CHAPTER 2
LITERATURE REVIEW

This chapter will discuss and present theories and references supports in the making of this research to overcome the problems.

2.1 Inventory Concept and Theory

Pujawan and Mahendrawathi (2010) said an inventory throughout the supply chain has major implications for the financial performance of a company. The amount of money that is embedded in the form of inventory is usually very large so the inventory is one of the most important assets owned by supply chain. Tersine (1994) states the basic understanding of inventory is the number of existing material at specific time intervals.

In the energy industry, particularly electricity in this case, the availability of materials is very important. Availability of primary material is an absolute must and required to be met immediately. Therefore it is necessary and material control strategies can be implemented in order fulfillment.

2.1.1 Material Requirement and Classification

Material requirements can be seen from the usage pattern. According to its use, the material can be divided into continuous and intermittent. Characteristic patterns of materials that are continuous is always used for each month. Meanwhile, the characteristic of intermittent pattern is when usage patterns are not always used for each month. Ghobbar (2002) says that the material has a pattern of continuous use is a type of fast moving material, while the material that has intermittent usage patterns can be classified into intermittent demand, erractic demand, lumpy demand, and slow moving.

a. Intermittent Demand

   Categorized with random demand (where many periods without request).

b. Erractic demand

   Categorized as demand with an erratic pattern and characterized by variations in the size of a period of high demand.

c. Lumpy demand

   Categorized as demand that has zero demand patterns randomly in the long term.

d. Slow moving

   Categorized as a request that does not have a large variation between the needs and the quantity of demand interval.

An approach to categorize intermittent demand is in two parameters, which is coefficient of variation (CV) and average demand interval (ADI). ADI is the span of time between the demand and the coefficient of variation (CV). Limit values for CV and ADI can be seen in Figure 2.1

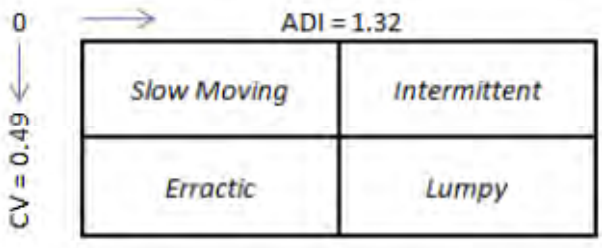

Figure 2.1 Item Demand Pattern (Ghobbar, 2002)

Determining the value of CV and ADI can be obtained by using a formula. Figure 2.1 is shown how to calculate the ADI.

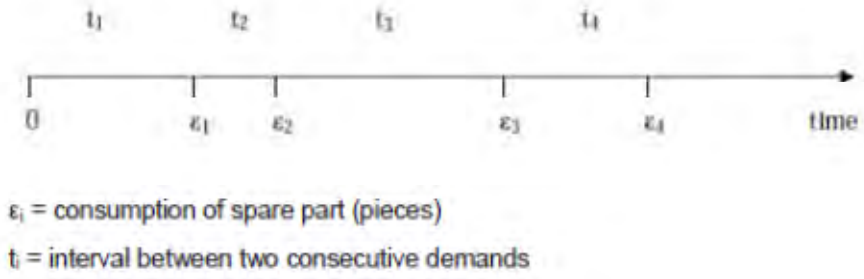

Figure 2.2 Example Usage of Material Intermittent

$$ADI = \frac{\sum_{i=1}^{N} t_1}{N} \quad \text{..... (1)}$$

$$CV = \frac{\sqrt{\frac{\sum_{i=1}^{N}(\varepsilon_i - \varepsilon)^2}{N}}}{\varepsilon} \quad \text{..... (2)}$$

where,

$$\varepsilon = \frac{\sum_{i=1}^{N} \varepsilon_1}{N} \quad \text{..... (3)}$$

The value of N for the ADI is the number of periods (months) without a value of 0, whereas for CV is the entire period (month).

Determining demand value is strongly influenced by the demand forecasting. Forecasting demand or needs is very vital in the planning and controlling process of all areas including logistics, marketing, production, and finance

Demand forecasting can be classified into dependent or independent. Dependent demand is a vertical sequence characteristic of purchase and manufacture situations. One example of this is dependent vertical components such as tires that being assembled to be finished goods (cars). Therefore demand for tires depends on a car assembly schedule. Horizontal dependent demand is a

special situation where the promotional item or operator manual is merging in each item. For example, every purchase of a tennis racket got a tennis ball. In this case a tennis ball forecasting demand is depends on forecasting of tennis racket.

The importance thing in estimating demand is to combine forecasting, supply status, and the planning required.

2.1.2 Inventory Classification

Silver (1998) says that based on the shape, stock can be classified into raw materials, intermediate goods and finished goods.

Based on its function, can be differentiated by:

1. Pipeline / Transit Inventory.
   Inventories arise due to delivery and leads time from one place to another. This inventory will be huge if distance and delivery time is long.
2. Cycle Stock
   Have a given cycle, at the time of delivery in large quantities, then decline gradually due to worn or sold until finish or nearly finish.
3. Safety Stock.
   Serve to overcome uncertain demand or inventory uncertainty. The size of the safety stock related to the cost of inventory and service level.
4. Anticipation Stock.
   Inventory is needed to anticipate an increase in demand due to the seasonal nature of demand for a product.

Pujawan and Mahendrawathi (2010) said that inventories can also be classified based on the nature of the dependence between the needs of one item to another. Items depends on the needs of the other items is called dependent demand items. Conversely, the needs for independent demand items are not

depending on the needs of other items. Classification is done by the management of both types of items are usually different.

2.1.3 Inventory Cost

Costs influential in inventory control activities are:

1. Purchase costs

   The purchase price per unit of the item when the item is available from external sources or production cost per unit if the item is produced internally.

2. Procurement costs

   Divided into two:

   a. The Ordering Cost.

      All expenses incurred to bring in goods from outside.

   b. Manufacturing cost (setup cost).

      All expenses incurred in preparing the production of a product.

3. Storage costs

   All expenses incurred due to store goods, which include the cost of having inventory, obsolescence charges, impairment charges, depreciation of goods, expired charge, the cost of insurance and administrative costs.

4. Inventory shortage costs.

   Is the cost of the losses due to disruption of the production process and lose the opportunity to benefit due to exhaustion of supplies, the cost can be measured:

   a. Quantity that cannot be met, measured from profits lost because they could not meet the demand or loss due to interruption of the production process.

   b. Fulfillment time is measured by the time required to comply with the time unit warehouse.

c. Emergency procurement costs, i.e. costs incurred through the emergency provision does usually lead to greater cost than normal procurement.

2.1.4 Inventory Performance Measured

Pujawan and Mahendrawathi (2010), the principle of inventory performance should be oriented on operating efficiencies and customer service. Both of these are often contradictory, if not made fundamental changes to the system, increasing service level usually implies an increase in inventories. Some of the measures that can be used to monitor the performance of the stock are:

1. Inventory turnover.

   This is to see how quickly the product flow relative to the average amount stored as inventory. Its value can be measured for each individual product or in the aggregate represent a group or the entire product. Turnover rate is usually measured in a year.

2. Inventory days of supply.

   Defined as the average number of days a company can operate with the amount of inventory on hand. This measure can actually be said to be align with the inventory turnover rate.

3. Fill rate.

   Define as the percentage of items that are available when requested by the customer. Fill rate can be measured for each of the products individually or in the aggregate for the entire product. To create an effective supply chain management, the company may need to distinguish the target fill rate for each customer and each item.

   Ehap H. Sabri and Benita M. Beamon (1999) described fill rate rate is a common measure of service level performance. Fill rate measures the percentage of orders filled immediately. Flexibility can be defined as the ability to respond to customer requirements.

Two types of flexibility, which depend on supply chain (SC) configuration, are considered here: volume flexibility, and delivery flexibility. Volume and delivery flexibility are defined in as the ability to change the level of produced products and planned delivery dates, respectively. Volume flexibility, which is measured by capacity slack, is commonly used in industry. However, delivery flexibility, which is measured by lead-time slack, is not used often in industry or in literature. This is because the majority of inventory and SC models in literature assume fixed lead times.

1. Service Level (Service Level)

Service level is a value set by the company, which is included in the calculation of product inventory in order to meet the needs of customers (Ballou, 2004). Some class service level on product inventory is allowed. Value of service level is usually a percentage, which is the maximum limit of 100%, which means that consumers always get the items ordered quickly. Value of service level is usually determined by the prevailing policies in an enterprise.

Advantages election service level 100% value for the company is:

- The certainty of having product inventory.
- The level of good customer service.

Losses election service level 100% value for the company is:

- High inventory of products stored in the warehouse
- It takes funds to undertake the investment

2.1.5 Economic Order Quantity

One simple model that can be used to determine the economic order is a model of economic order quantity (EOQ). These models consider two inventory cost, i.e. the cost of order and storage costs. Cost mentioned here is fixed costs that come out every order is made and is not dependent on the size or volume of

orders. While storage costs incurred due to the company store items during a given period.

EOQ model made with a number of assumptions. That is, the model can only be used quite well if a number of assumptions are met or at least closer. The assumption is the demand for an item to be continuous with a uniform rate, only one product is considered, the grace period is fixed, the ordered goods are readily available, there is no shortage of supply, and there is no quantity discount.

If the number of requests already be known, then it can assume the number of requests and the grace period (lead time) is fixed and known number. Optimum order quantity can be calculated by analyzing the total cost. The total cost is the total cost of ordering (ordering or set-up cost) plus the cost of storage (holding cost) in a given period. Pujawan and Mahendrawathi (2010), EOQ formulation is derived from the formulation of the total cost.

It can be seen from the following equation:

Total Cost = Ordering Cost + Storage Cost.

$$TC = \frac{D}{Q} C_b + \left(\frac{Q}{2}\right) h_b \quad \text{.....(4)}$$

Where,

Q = size of the reservation

D = needs per year (units / year)

C_b = cost of ordering (USD / order)

h_b = storage cost (/ unit number / year)

Then the EOQ formulation is:

$$Q_{opt} = \frac{\sqrt{2C_b D}}{h} \quad \text{.....(5)}$$

Where the value of h must be converted into the number of dollars per unit per year.

2.2 Control Inventory Mechanism

Silver (1998) in conducting inventory control, there are three fundamental questions, namely:

1. How often the inventory status should is determined.
2. When should reorder placed.
3. How big is recharging done.

Control systems are classified such as:

1. Deterministic Inventory System

   According Tersine (1994), is a deterministic inventory model inventory system where all parameters and variables are known with certainty. Determistik inventory model facilitates the analysis and an initial inventory systems approach, as it is the starting point for describing the phenomenon of inventory. The model developed in this system is often referred Lot Sizing Model. This is because a decision about the inventory system is based off of the quantity of items (lot size). Lot size model of the simplest is the Economic Order Quantity (EOQ)

2. Probabilistic Inventory System

   Is a model that assumes that the parameters that indicate the presence of uncertainty and is a random variable. In the inventory system, the uncertainty is mainly related to the number of requests (demand quantity) and lead time. Uncertainty of demand and delivery time may lead to a shortage

Inventory (stock out). This will affect the unfulfillment of customer satisfaction. In anticipation of this, policy to hold safety stock was created. In measuring the availability of raw materials is based on the level of customer service level. Tersine (1994), customer service level is the ability to meet

consumer demand from existing inventory. The value of customer service levels will affect the expected safety stock, thus minimize inventory shortages. Shortage occurs when the demand during lead time exceeds the reorder point. According to Silver (1998), there are four types of control system that is a form of the inventory policy, which are:

a. Continuous Review Inventory System.

Continuous review inventory system (Q-System) is to constantly monitor and watch inventory levels continuously. Order will be done at the level of inventory reaches reorder point level or below.

The system is divided into two, which are:

1. Order Point Order Quantity (s, Q) system.

The inventory order which will be conducted by Q when inventory levels reach reorder point r or lower. In other words, the position of inventory will be used to trigger an order. The parameters of (Q, R) or (s, Q) reorder point is the level of inventory position, which a reservation has to be done. While the order quantity (Q) is the decision of the number of units ordered each time when ordering.

2. Order Point, Order Up to Level (s, S) system.

It is a system whereby inventories have reached the level s or lower than the reservation will be done until the inventory level S. This system is also a continuous review, where inventory replenishment done when the position down to the reorder point s or lower. Similarly with the system (s, Q), the variable replenishment quantity used or ordered to positions in the order-up-to level S, where:

$$S = s + Q \quad \text{.....(6)}$$

b. Periodic Review Inventory System

Periodic time review policy (T-Systems) monitors and watch inventory levels at the same interval T. This means that the period of the order always remains, but the order quantity varies.

The system is divided into two, which are:

1. Periodic Review, Order Up to Level (R, S) system.
   An inventory system in every review reach the period R, there will be order until the inventory level reaches S.
   This system is known as the replenishment cycle system which is used by companies that not use computer control, where every R units ordered enough time to reach the level of inventory at S.
2. (R, s, S) system, a combination of (s, S) and (R, S).
   In this inventory system, when the inventory level to the level s or lower, it will be order until the inventory level S, and if it's above or not reached, it does not do anything until the next review period R.
   This system is a combination of the system (s, S) and (R, S). Each unit time inventory positions examined, if the position is right or below the reorder point s, then the ordering done enough to reach the S.
   When a position is above s, then nothing is done until the next review.

2.3 Reorder Point (s) and Maximum Stock (S)

Reorder point (ROP) is the point at which a material performs an ordering again. This is done in order to avoid gaps in warehouse stock material. In calculate ROP it is strongly influenced by elements of lead time uncertainty. Lead time itself is the arrival time of the material ordered until it is received. Maximum stock (S) is the maximum amount of stock material.

Calculation formula is:

$$ROP = d \times l + \text{safety stock} \quad \text{.....(7)}$$

Where,

d = average demand per day

And,

$$\text{Maximum Stock} = ROP + EOQ \quad \text{.....(8)}$$

Where,

ROP = Reorder Point

EOQ = Size booking

2.4 Safety stock

Pujawan and Mahendrawathi (2010), safety stock is a stock that serves to protect the safety errors in predicting demand during lead time. So that the safety stock will function if at some point the real demand is greater than the average demand. Safety stock will be very easy to come by if the data demand during lead time is normally distributed. Then the following formulation:

$$SS = Z \times s_{dl} \quad \text{.....(9)}$$

Where,

SS = safety stock

Z = the value of the inverse of the normal distribution that correlated with a probability (service level)

S_{dl} = standard deviation of demand during lead time

The value of safety stock depends on the uncertainty of supply and demand. In normal circumstances the supply uncertainty is represented by the standard deviation of lead time from the supplier. While the demand uncertainty is

represented by the standard deviation of the amount of requests per period. Sdl value can be found by the formula:

$$S_{dl} = \sqrt{(d^2 \, x \, s_l^2 + \, l \, x \, s_d^2)} \quad \text{.....(10)}$$

Where,

S_{dl} = standard deviation of demand during lead time

d = the average demand

S_l = standard deviation of lead time

l = lead time

S_d = standard deviation of demand

Using the formula above, we can see four of the conditions addressed by Figure 2.3.

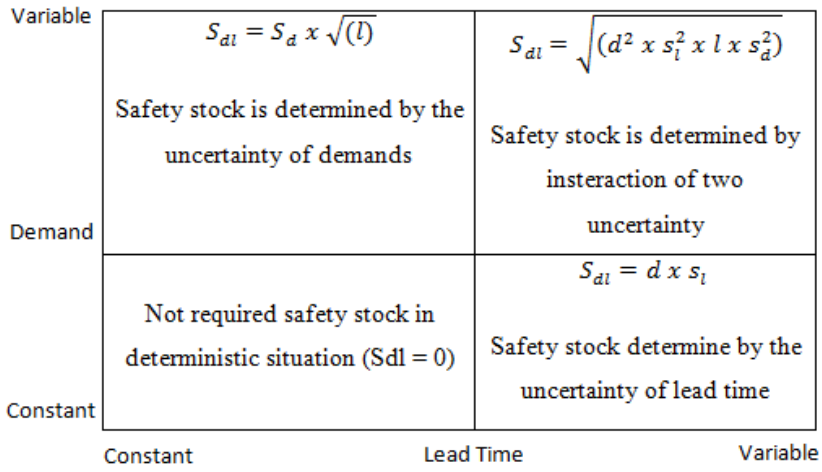

Figure 2.3 the interaction between demand and the lead time on the determination of safety stock

2.5 Maintenance Concept

In general understanding of maintenance it can be interpreted as activities to preserve or maintain plant equipment and facilities or conduct maintenance activities, corrective adjustments, and replacement of some of the

equipment needed for the facility to perform at the expected and reliable condition, always in a condition ready for use. Maintenance can be divided into two, which are, preventive maintenance and corrective maintenance.

b. Preventive Maintenance.

Maintenance activities are carried out prior to the failure or damage to a system or component. Some of the preventive maintenance goal is to detect early failure or malfunction, failure minimilisation. Preventive maintenance can be divided into:

1. Time Directed Maintenance.

   It can be done if time variable of a component or system is known. Appropriate maintenance policy to be applied to time directed maintenance is periodic maintenance and on-condition maintenance. Periodic maintenance is preventive maintenance on a scheduled basis that aims to replace a component or a system based on a specific time interval. On-condition maintenance, it is carried out maintenance activities based on operator policy.

2. Condition Base Maintenance.

   It is a preventive maintenance activities based on a specific conditions of a component or system, which aims to anticipate a component or system that was not damaged. Since the variable timing is not known for sure, the policy is in accordance with the conditions of predictive maintenance. Predictive Maintenance is a maintenance activity that was done by using a monitoring system, such as analysis and composition of the gas.

3. Finding Failure.

   It is a preventive maintenance activity aims to detect hidden failure, conducted by check the hidden functions periodically to ensure that when a component fails.

4. Run to Failure.

   Classified as preventive maintenance because of an accident that could happen in some of the equipments. Also referred to as a no maintenance schedule as conducted if no preventive measures are effective and efficient to do, if precautions are too expensive or the impact of the failure is not very essential (not too powerful).

c. Corrective Maintenance.

   It is an activity maintenance undertaken to address the failure or damage is found during the time of preventive maintenance. In general, corrective maintenance is not a scheduled maintenance activity, as carried out after a damaged component aims to restore the reliability of a component or system to its original state.

   In this research, the trigger is to perform maintenance of the request. Upon request, the maintenance's done a new installation and repair.

2.6 Monte Carlo's Simulation

Monte Carlo simulation is a kind of probabilistic simulation approach the solution to a problem with a process of random sampling of the data (Tersine, 1994). Monte Carlo simulation is basically an experiment whose goal is to estimate the distribution of the output variable whose value depends on the input variables that have the probability that the Monte Carlo simulation uses random numbers and probability distribution in its calculations.

Steps in performing Monte Carlo simulations are:

1. Determine the probability distribution of the variables obtained from historical data.
2. Convert frequency distribution to a cumulative distribution.
3. Making the interval from the cumulative distribution for the random digits of each variable.

4. Determining the value of a random.
5. Insert random number into a variable interval variable to obtain the specific value for the simulation.

Random data is used to describe the movement of any random variable from time to time close to the real situation of an event. Monte Carlo simulations form a stochastic model of the real situation and perform sampling experiments on the model. The basic idea of Monte Carlo simulation is to generate value to the variable of the model. In this research, Monte Carlo simulation is used to generate demand, Monte Carlo simulations will show simulation results that would resemble the model, in this case historical demand data that Monte Carlo will give an approximate value of a query requests from historical data.

Result simulation applied if the demand is meeting with the predicted forecast.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter outlines the stages of the research methodology that was being conducted in this research. The flowchart of the methodology can be seen in Figure 3.1.

3.1 Problem Identification and Formulation

Here we defined a series of activities to find the inventory problems in PT ABC which we thought was significant to disbenefit the company. This research focused on the PT ABC's material inventory categorized as Non MRO materials, to optimized the critical materials with intermittent demand and improved the quality of service of SCM Team (In this case is Warehouse Inventory Team) to the Maintenance Team. Once the inventory problems identified, then the next step was to formulate the problems to assign the matter to be raised in this research.

3.2 Literature Review and Field Observation

It was the reviewed activities of learning theories that support this study in order to solve the existing problems, so that these problems can be solved with the use of the existing theory or methods. Meanwhile, a field observation conducted in order to explore the real situation in the research object so that research questions or problems can be defined more accurately.

3.3 Data Collection

Pertinent data was being collected to support the analysis. The data collected from PT ABC, Duri is as follows:

1. Material consumption data. Material here referred to turbine mechanical / electrical spare parts material in the company's warehouse system, focus on Non MRO materials categorisation.
2. Material data is using 3 (Three) years company's data from Jan 2010 up to Dec 2012.
3. Material price data.
4. Inventory Cost is 20% from the material price. It is derived from 10% cost of capital, 1 % property tax, 3% Obsolescence, 1% shrinkage, 4% storage cost and 1% administration cost.
5. Order cost is average by $35. Order cost was cost for procurement and warehouse activities such as cost when procuring the material started with contract preparation cost (bidding process cost until contract awarder). The average was derived from calculation on the total above overhead cost divided by purchase ordered in a year.

The data above was taken from warehouse documents of PT ABC, where the data is company's classified data. The data obtained in the form of a retrieved soft file of JDE System parts inventory.

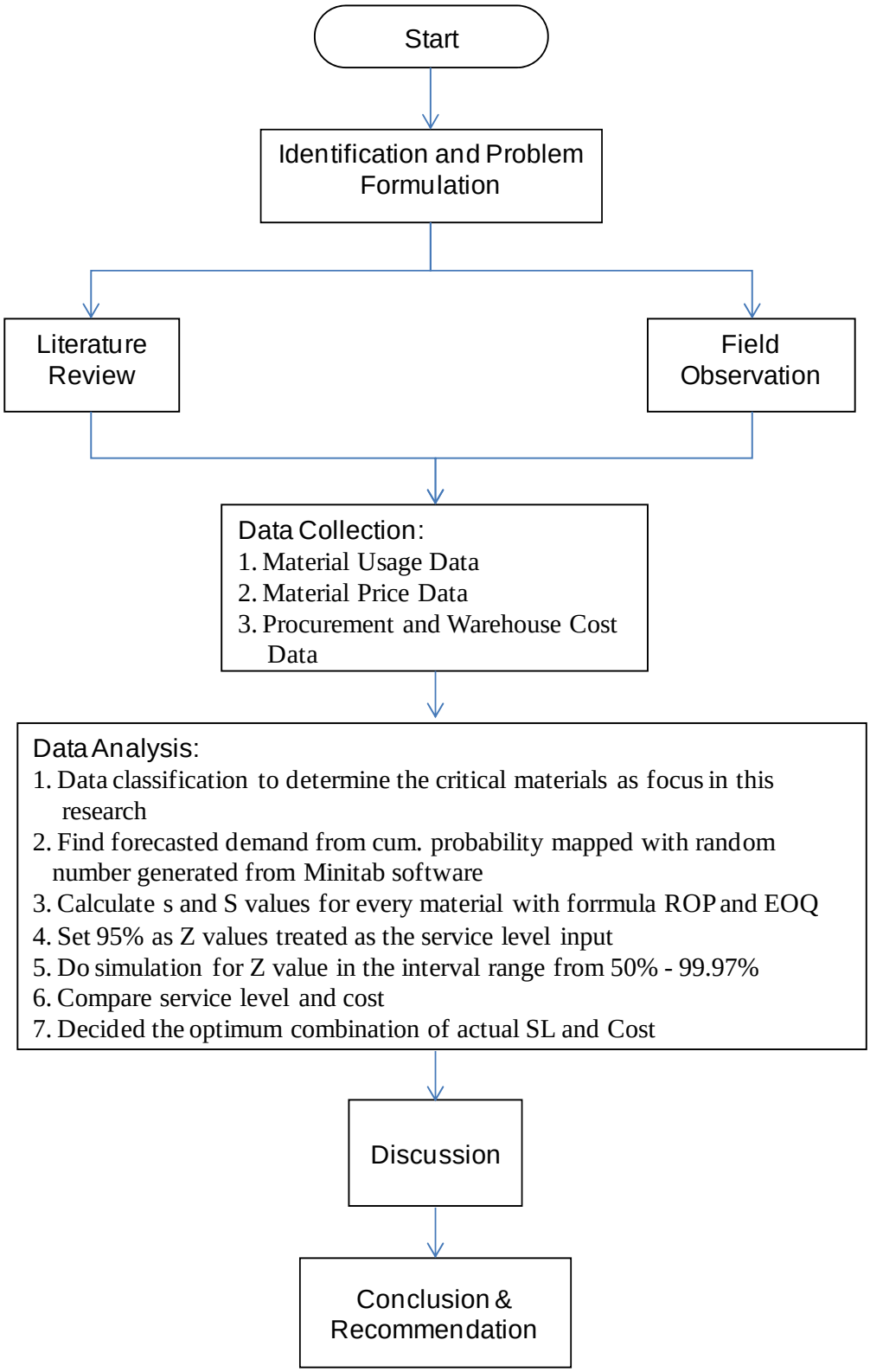

Figure 3.1 Research Methodology Flow Chart

3.4 Data Analysis

The subsequent data that have been obtained for data processing was being used as a raw data to solve problems in this research. These data were analyzed with the use of methods or models.

Data processing was being done by performing classification of materials to identify the critical and non critical ones. The critical materials were further being a focus in this research. After classification completed, we were continued classify the critical equipment's demand status: continuous (fast moving) and intermittent demand. Intermittent was divided on intermittent demand, erratic demand, lumpy demand, and slow moving.

This classification was based on study literature being performed in chapter two by calculation the ADI (Average Demand Interval) and CV (Coefficient of Variation). It is slightly different with company's current inventory classification where as we need to improve the company's classification criteria. After analyzed the use of materials, we focused to do improvement in materials with intermittent demand status. Then, we will determined the appointed material's EOQ, ROP, Max inventory, and Safety Stock. The next step was conducted an analysis to determined the material fulfillment strategy.

Simulations conducted were influenced by several aspects such as the cost of holding cost, order cost. Simulation steps can be seen in Figure 3.2.

3.4.1 Setting Parameters

This stage was to determined parameters of inventory based on the formula of the (s, S) model where s is the reorder point and S is maximum stock on each of the critical materials which were categorized as intermittent, erractic, lumpy demand, and slow moving's demand.

3.4.2 Inventory Simulation

The objective of Monte Carlo simulation was to improve the value of s and S that were initially obtained from the formula. The formula were based on the assumption that demand is normally distributed. In reality, demand may not be normally distributed, especially for items with slow demand or normally categorized as slow moving items. When demand is not normally distributed the optimum value of s and S may be smaller or larger than those obtained from the formula.

Simulations were being performed using data generated from random numbers to represent demand following the distribution of the empirical data. Demand in the maintenance of this research was a new installation requested and change requested. In the calculation, the needs for the new and for the replacements have been merged into one. Historical figures was the result of the merger, it was used as a basis for determining the distribution of demand which would then be used to generate the forecasted demand numbers with Monte Carlo simulation approach.

Z value is the value of the inverse of the normal distribution that correlated with a probability (service level). It reflects the probability of no stockout when material is needed . Since the demand distribution does not follow a normal distribution while the formulae to set the inventory parameters were based on the assumption of normal distribution, it is necessary to search the optimal value of s and S surrounding those obtained from the formulae. In this study we initially input the s and S values as obtained from the formulae. Later, we decrease and increase those s and S values and compared both the achieved service level and costs. The different service level input is used to obtain the Z value.

SS = Safety Stock = SS = Z x sdl standard deviation of demand during lead time

Meanwhile, service level is the Service level is a value set by the company, which is included in the calculation of product inventory in order to meet the needs of customers (Ballou, 2004).

SL = Annual demand / EOQ (in %)

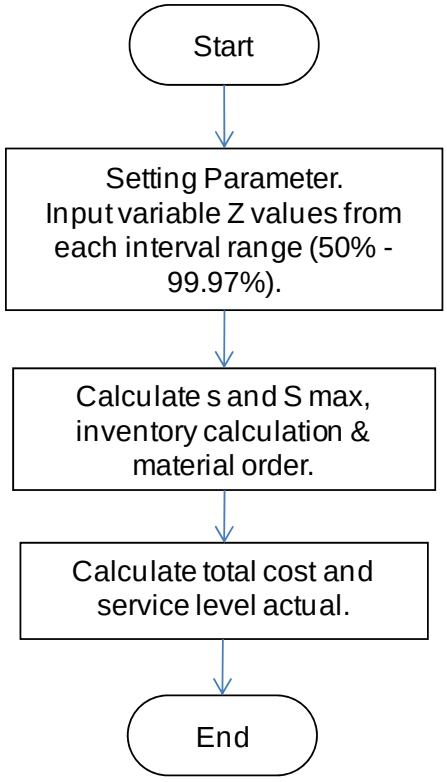

Figure 3.2 Simulation Flow Chart

3.5 Discussion and Analysis

At this stage, analyse data that has been discussed. The analysis aimed to determine the most ideal material circumstances. By determining the different variants of the maximum stock level with certain ROP value, the actual service level and inventory cost were being produced to achieved the most optimum level.

3.6 Suggestion and Conclusion

It is the final step of the research, after all data were processed and analyzed. The conclusion can be drawn about the research and suggestions will be presented to the authors that later can be used as a reference if required. The conclusion and suggestion made in order to summarised the most ideal material circumstances and ssuggested for improvement.

CHAPTER 4
DISCUSSION AND ANALYSIS

This chapter performed data collection, processing and analysis of results. Collection of data obtained from the company in the form of documents, direct field observation and interviews with the parties concerned. After collecting the data, then the data are analyzed to meet the research objectives.

4.1 Data Collection

This section contains data obtained from the company which will be used for data processing. It is from material inventory system information that converted to excel spreadsheet.

Material demand data derived from company documents included demand, orders, and inventory data per month during Jan 2011 up to Dec 2012. There are 5 commodities of inventory items, consists of commodity code: e (Turbine Hardware), b (Electrical), c (Valve and Parts), a (Instrumentation and Parts), and d (Pump and Parts) under PT ABC warehouse system. The price of goods data also consisted in the document. Table 4.1 illustrates the value of inventory, demand and orders for one time. An example of material is Pump Parts. The existing lead time is less than 1 month due to company alteady has a contract with suppliers that can meet or faster than the targetted lead time (1 month).

Table 4.1Inventory, Demand and Order Data of Pump Parts Material

Commodity Code	Year	Month	Inventory	Demand	Period	Order	Receipt
Pump Parts	2010	1	234	1	1		
		2	255	1	1	22	22
		3	255	1	1	1	1
		4	256	0		1	1
		5	256	4	2	4	4
		6	230	26	1		
		7	274	0		44	44
		8	274	0			
		9	261	45	3	32	32
		10	260	1	1		
		11	256	5	1	1	1
		12	232	25	1	1	1
	2011	1	236	1	1	5	5
		2	213	23	1		
		3	235	8	1	30	30
		4	270	21	1	56	56
		5	269	1	1		
		6	277	6	1	14	14
		7	274	12	1	9	9
		8	266	9	1	1	1
		9	278	0		12	12
		10	303	1	2	26	26
		11	306	2	1	5	5
		12	307	0		1	1
	2012	1	307	0			
		2	301	6	3		
		3	300	1	1		
		4	300	0			
		5	301	0		1	1
		6	301	0			
		7	301	0			
		8	301	0			
		9	304	0		3	3
		10	303	1	7		
		11	299	4	1		
		12	289	11	1	1	1

Demand data for some presentation material can be seen in the figure 4.1 until 4.3 below. Some material is taken to demonstrate demand graphic for units in time.

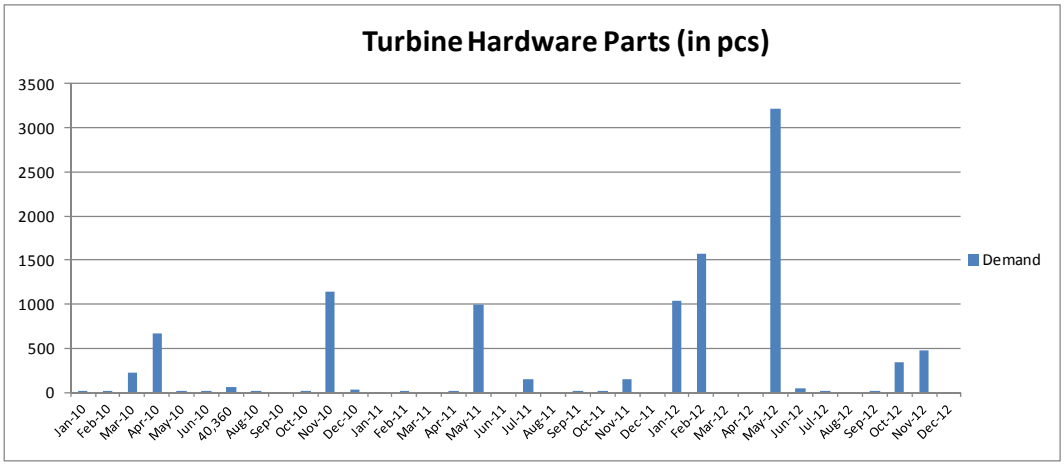

Figure 4.1 Graphs of Material Demand Data of Turbine Hardware Parts

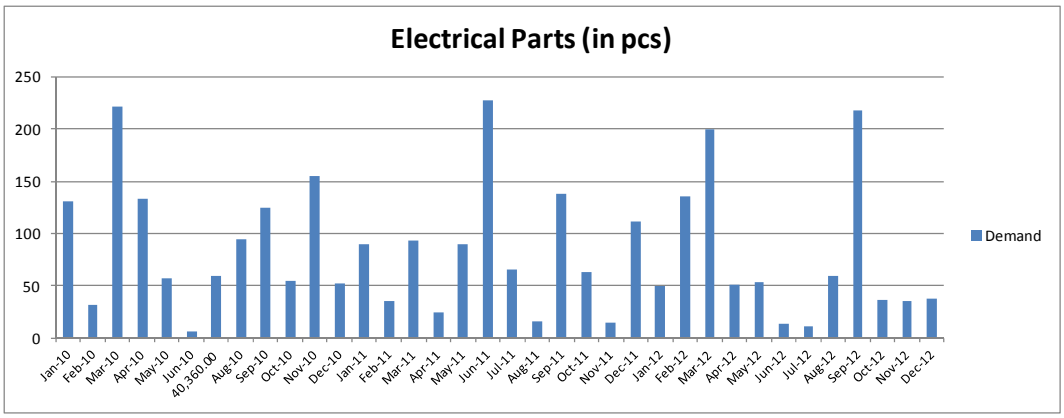

Figure 4.2 Graphs of Material Demand Data of Electrical Parts

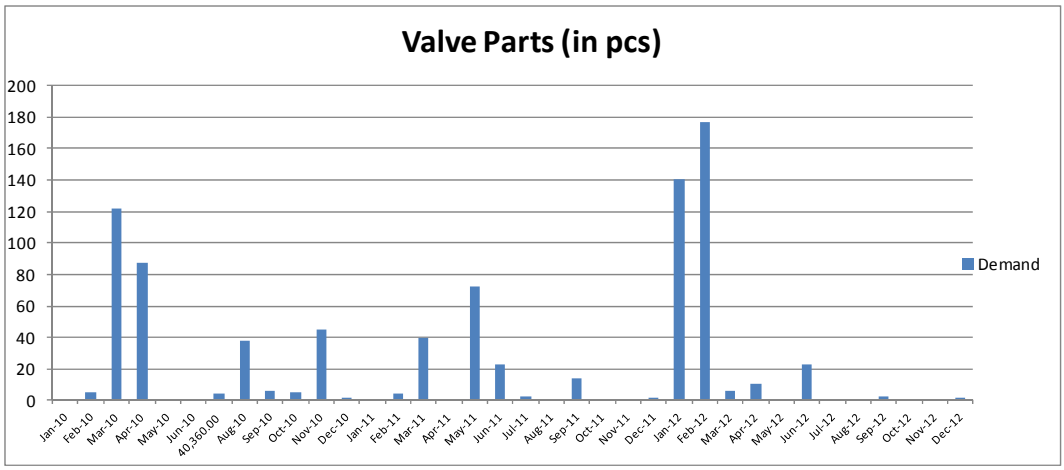

Figure 4.3 Graphs of Material Demand Data of Valve Parts

From the figure 4.1 – 4.3 above, it can be seen from the graph that the pattern of demand for the material Turbine Hardware, Electrical and Vale Parts materials is not always happening every month, some material demand occurs only a few months and the demand quantity is variative (not constant). This will be further analysing through material classification based on its CV (Coefficient of Variation) & ADI (Average Demand Interval).

In accordance with the limitations of this research, Table 4.2 will show a summary of materials with demand from Jan 2012 to Dec 2012.

Table 4.2 Material List with the Demand Quantity

Parts Commidity	Grouping Demand (Period)
Instrumentation Parts (a)	≥36
Electrical Parts (b)	
Valve Parts (c)	<36
Pump Parts (d)	
Turbine Hardware Parts (e)	

4.2 Data Processing

The data processing section contains stages of processing data that have been obtained.

4.2.1 Material Classification

In this study we deal with materials with high inventory value and low Turnaround Ratio. Step number one is to determine the criticality among the materials to be research. The criticality is analyzed based on its inventory value and TOR. From Box Plot analysis of 5 (Five) Commodity of Materials, we may find that material with commodity code e (Turbine Hardware), c (Valve and Parts) and d (Pump Parts) are critical items that need to be improved due to its highest inventory value and lowest TOR among other material commodity. Meanwhile the a (Instrumentation Parts) & b (Electrical) materials are the less critical ones.

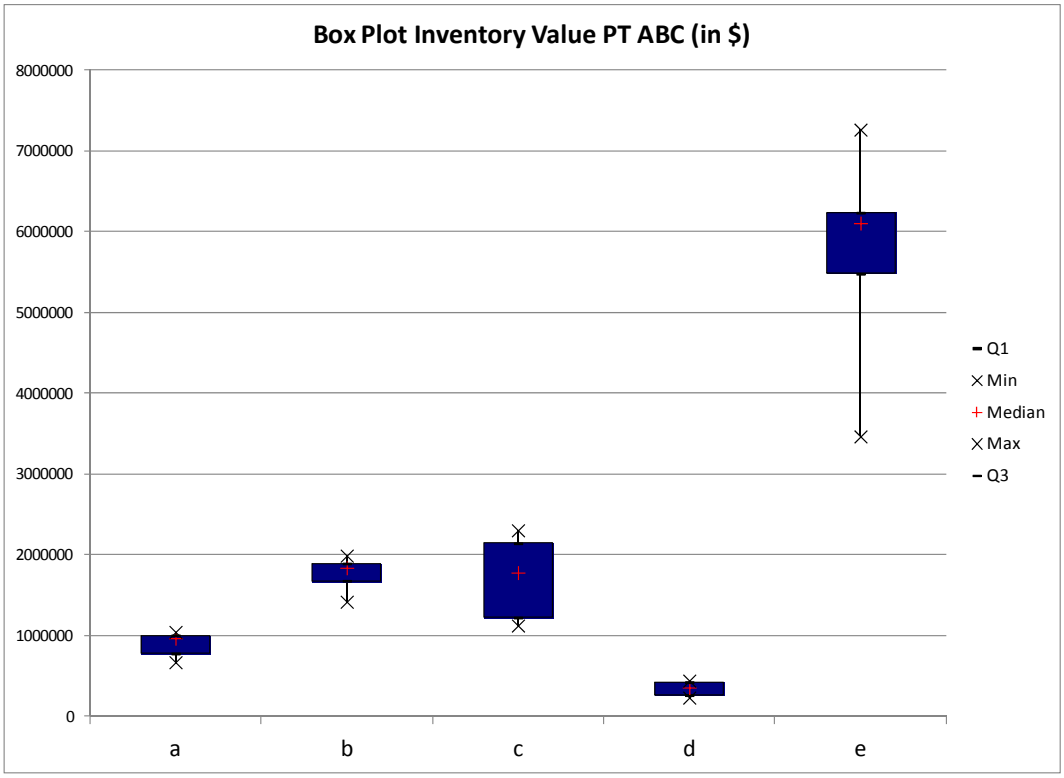

Figure 4.4 Box Plot Result Material Inventory Value

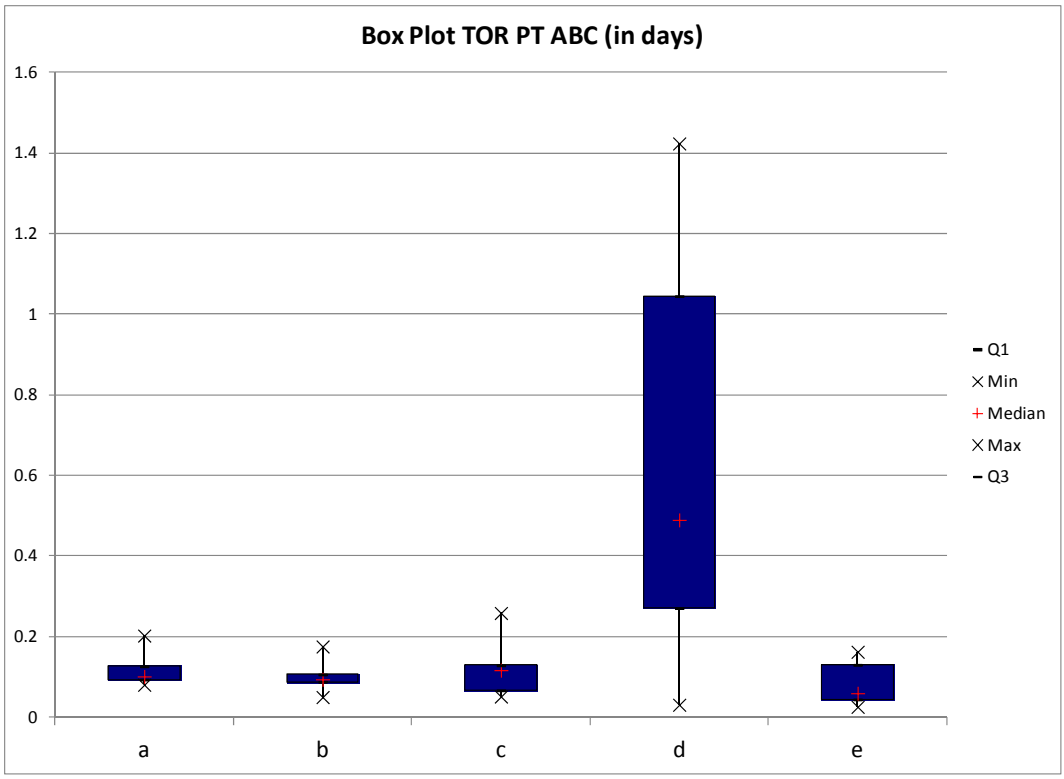

Figure 4.5 Box Plot Result Material Inventory TOR

Step number two in classification of material is performed based on the time between requests or ADI (Average Demand Interval) and Coefficient of Variation (CV). Whereby if the value is less than 1.32 then ADI classified material into a continuous pattern and if the value is greater than 1.32 ADI then classified it into intermittent pattern.

Ghobbar (2002) stated that intermittent demand can be classified into 4 types, which are Slow Moving, Intermittent, Erractic, and Lumpy demand. The basis of these groupings can be seen from the value of CV and ADI.

- CV values <0.49 and ADI values <1.32 included in the category of Slow Moving.
- CV values <0.49 and ADI values >1.32 included in the category of Intermittent.

- CV values >0.49 and ADI values <1.32 included in the category of Erractic.
- CV values >0.49 and ADI values >1.32 included in the category of Lumpy.

Table 4.3 Material Classification

No	Parts Commodity	CV	ADI	Demand Category	Demand Type
1	Instrumentation Parts (a)	0.87	1.00	Intermittent	Erractic
2	Electrical Parts (b)	0.74	1.00	Intermittent	Erractic
3	Valve Parts (c)	1.78	1.24	Intermittent	Erractic
4	Pump Parts (d)	1.55	1.5	Intermittent	Lumpy
5	Turbine Hardware Parts (e)	2.19	1.25	Intermittent	Erractic

From the table 4.3, it can be seen that 5 material, 4 (Four) of them were categorized as intermittent with type of Erractic demand. It is a demand with an erratic pattern that characterized by variations in the size of a period of high demand. The other 1 (One) is categorized as lumpy demand. It has zero demand patterns randomly in the long term.

From classification, then it will be grouped in a quadrant where Figure 4.1 shows the classification of the material is based on the average demand interval (ADI) and the lead time. This classification will indicate the type of demand from long or short demand where if lead time < 30 days is including the short usage categories and if lead time > 30 days is including long usage one.

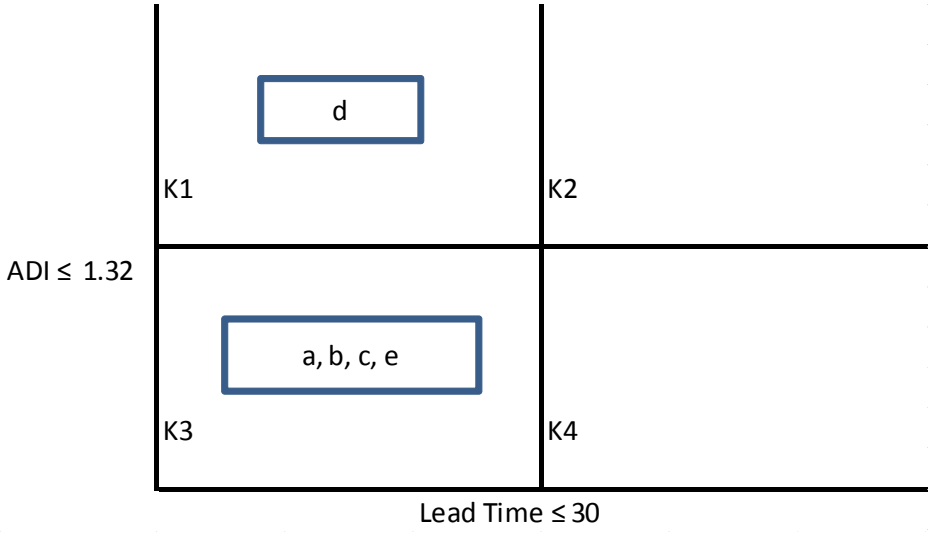

Figure 4.6 Material Classification based on ADI and LT

Quadrant III shows that the value of ADI is ≤ 1.32 and the lead time is ≤ 30 days. Most of the materials are classified in this quadrant where the material is a short usage category. Except Pump Parts fall in Quadrant I since it have value of ADI ≥ 1.32 and the lead time is ≤ 30 days. This material has bigger ADI value than in Quandrant III means that the it has longer demand interval between the frequencies in each of the demand.

4.2.2. Material Inventory Control

4.2.2.1 Determining Demand

In this research, a Monte Carlo simulation will be carried out. It will show the dynamics od demand, inventory, and replenishment for 60 monts. Demand is generated using random numbers and follows the past demand distribution.

Table 4.4 is shows demand distribution for material Pump Parts and the use of random numbers to generate simulated demand. The table shows only 20 of 60 data generated.

Table 4.4 Probability Calculation Material Pump Parts

Demand	Frequency	Proportion	Cum. Proportion	Interval Proportion
0	12	0.333	0.333	0.000 - 0.333
1	9	0.250	0.583	0.334 - 0.583
2	1	0.028	0.611	0.584 - 0.611
4	2	0.056	0.667	0.612 - 0.667
5	1	0.028	0.694	0.668 - 0.694
6	2	0.056	0.750	0.695 - 0.750
8	1	0.028	0.778	0.751 - 0.778
9	1	0.028	0.806	0.779 - 0.806
11	1	0.028	0.833	0.807 - 0.833
12	1	0.028	0.861	0.834 - 0.861
21	1	0.028	0.889	0.862 - 0.889
23	1	0.028	0.917	0.890 - 0.917
25	1	0.028	0.944	0.918 - 0.944
26	1	0.028	0.972	0.945 - 0.972
45	1	0.028	1.000	0.973 - 1.000
0	12	0.333	0.333	0.000 - 0.333
1	9	0.250	0.583	0.334 - 0.583
2	1	0.028	0.611	0.584 - 0.611

Then random numbers are generated from the uniform of distribution. The demand is according to the numbers which assumed as the proportion. Simulation results are shown in Table 4.5. It shows only 20 out of 60 demand data generated.

Table 4.5 Random Numbers Generated from Demand Forecasting Material Pump Parts

No	Generate Random	Demand
1.	0.725	6
2.	0.087	0
3.	0.454	1
4.	0.527	1
5.	0.052	0
6.	0.111	0
7.	0.546	1
8.	0.727	6
9.	0.233	0
10.	0.081	0

No	Generate Random	Demand
11.	0.080	0
12.	0.027	0
13.	0.753	8
14.	0.636	4
15.	0.980	45
16.	0.765	8
17.	0.735	6
18.	0.408	1
19.	0.373	1
20.	0.354	1

4.2.2.2 Simulation

Simulation performed using Microsoft Excel software. Steps of simulation are:

1. Calculate Inventory to t (It) period.
   Formula: $lt = lt - 1 + Ort - dt$
   Where,
   $lt - 1$= Inventory in previous period.
   Ort = Order received in t period.
   dt = demand in period t.
2. Calculate order to t (Ot) period.
   Formula: $0t = S - (lt - 1 + On\ Order\ t - 1)$
   Where,
   S = Maximum Stock.
   $On\ Order\ t - 1$ = Order from previous period which have not been arrived.
3. Determine demand, derived from historical and do the forecasting use Monte Carlo simulation with Minitab software.
4. Receipt, orders came in period t.
5. Lead time, assumed the lead time is 1 (One) month.
6. Holding cost, the value of holding cost is 20% of the price of goods.

It is derived from:

10% Cost of Capital.

1% Property Tax.

3% Obsolescence.

1% Shrinkage.

4% Storage Cost.

1% Administration Cost.

% value is an assumption from the company corporate information.

7. Value of the order cost is $35.

From total 5 types of commodity code of total materials inventoried in January 2010 to Dec. 2012; all materials were performed in the simulations. The selection of these materials is selected based on their criticality to PT ABC operation. The criteria are inventory value and TOR.

4.2.2.3. Simulation Result

Table 4.6 and Table 4.7 show the results of simulation calculations with Microsoft Excel on Pump parts material. In the table, 30 out of 60 simulation period results is presented. For each material, simulations is carried out by varying the value of Z inputted in determined the safety stock, from 50% to 99.7% and evaluate the values of s and S to obtain the most optimum total cost and actual service level equal or exceed 95%.

Table 4.6 Examples of Simulation Results of Pump Parts material Calculated with Formula s, S

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	234	1	26	0	0	0	1
		2	255	1	26	22	22	0	1
		3	255	1	26	1	1	0	1
		4	256	0	26	1	1	0	1
		5	256	4	26	4	4	0	1
		6	230	26	26	0	0	0	1
		7	274	0	26	44	44	0	1
		8	274	0	26	0	0	0	1
		9	261	45	26	32	32	0	1
		10	260	1	26	0	0	0	1
		11	256	5	26	1	1	0	1
		12	232	25	26	1	1	0	1
	2011	1	236	1	26	5	5	0	1
		2	213	23	26	0	0	0	1
		3	235	8	26	30	30	0	1
		4	270	21	26	56	56	0	1
		5	269	1	26	0	0	0	1
		6	277	6	26	14	14	0	1
		7	274	12	26	9	9	0	1
		8	266	9	26	1	1	0	1
		9	278	0	26	12	12	0	1
		10	303	1	26	26	26	0	1
		11	306	2	26	5	5	0	1
		12	307	0	26	1	1	0	1
	2012	1	307	0	26	0	0	0	1
		2	301	6	26	0	0	0	1
		3	300	1	26	0	0	0	1
		4	300	0	26	0	0	0	1
		5	301	0	26	1	1	0	1
		6	301	0	26	0	0	0	1
		7	301	0	26	0	0	0	1
		8	301	0	26	0	0	0	1
		9	304	0	26	3	3	0	1
		10	303	1	26	0	0	0	1
		11	299	4	26	0	0	0	1
		12	289	11	26	1	1	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	283	6	26	0	0	0	1
		2	283	0	26	0	0	0	1
		3	282	1	26	0	0	0	1
		4	281	1	26	0	0	0	1
		5	281	0	26	0	0	0	1
		6	281	0	26	0	0	0	1
		7	280	1	26	0	0	0	1
		8	274	6	26	0	0	0	1
		9	274	0	26	0	0	0	1
		10	274	0	26	0	0	0	1
		11	274	0	26	0	0	0	1
		12	274	0	26	0	0	0	1
	2014	1	266	8	26	0	0	0	1
		2	262	4	26	0	0	0	1
		3	217	45	26	0	0	0	1
		4	209	8	26	0	0	0	1
		5	203	6	26	0	0	0	1
		6	202	1	26	0	0	0	1
		7	201	1	26	0	0	0	1
		8	200	1	26	0	0	0	1
		9	200	0	26	0	0	0	1
		10	175	25	26	0	0	0	1
		11	175	0	26	0	0	0	1
		12	174	1	26	0	0	0	1
	2015	1	174	0	26	0	0	0	1
		2	165	9	26	0	0	0	1
		3	165	0	26	0	0	0	1
		4	164	1	26	0	0	0	1
		5	164	0	26	0	0	0	1
		6	153	11	26	0	0	0	1
		7	147	6	26	0	0	0	1
		8	147	0	26	0	0	0	1
		9	147	0	26	0	0	0	1
		10	122	25	26	0	0	0	1
		11	122	0	26	0	0	0	1
		12	101	21	26	0	0	0	1

Table 4.7 Simulation Result Example for material Pump Parts from s, S alternative

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Existing	2010	1	234	1	15	0	0	0	1
		2	255	1	15	22	22	0	1
		3	255	1	15	1	1	0	1
		4	256	0	15	1	1	0	1
		5	256	4	15	4	4	0	1
		6	230	26	15	0	0	0	1
		7	274	0	15	44	44	0	1
		8	274	0	15	0	0	0	1
		9	261	45	15	32	32	0	1
		10	260	1	15	0	0	0	1
		11	256	5	15	1	1	0	1
		12	232	25	15	1	1	0	1
	2011	1	236	1	15	5	5	0	1
		2	213	23	15	0	0	0	1
		3	235	8	15	30	30	0	1
		4	270	21	15	56	56	0	1
		5	269	1	15	0	0	0	1
		6	277	6	15	14	14	0	1
		7	274	12	15	9	9	0	1
		8	266	9	15	1	1	0	1
		9	278	0	15	12	12	0	1
		10	303	1	15	26	26	0	1
		11	306	2	15	5	5	0	1
		12	307	0	15	1	1	0	1
	2012	1	307	0	15	0	0	0	1
		2	301	6	15	0	0	0	1
		3	300	1	15	0	0	0	1
		4	300	0	15	0	0	0	1
		5	301	0	15	1	1	0	1
		6	301	0	15	0	0	0	1
		7	301	0	15	0	0	0	1
		8	301	0	15	0	0	0	1
		9	304	0	15	3	3	0	1
		10	303	1	15	0	0	0	1
		11	299	4	15	0	0	0	1
		12	289	11	15	1	1	0	1

	Year	Month	Inventory	Demand	S Simulation	Order	Receipt	On Order	L
Forecasting	2013	1	283	6	15	0	0	0	1
		2	283	0	15	0	0	0	1
		3	282	1	15	0	0	0	1
		4	281	1	15	0	0	0	1
		5	281	0	15	0	0	0	1
		6	281	0	15	0	0	0	1
		7	280	1	15	0	0	0	1
		8	274	6	15	0	0	0	1
		9	274	0	15	0	0	0	1
		10	274	0	15	0	0	0	1
		11	274	0	15	0	0	0	1
		12	274	0	15	0	0	0	1
	2014	1	266	8	15	0	0	0	1
		2	262	4	15	0	0	0	1
		3	217	45	15	0	0	0	1
		4	209	8	15	0	0	0	1
		5	203	6	15	0	0	0	1
		6	202	1	15	0	0	0	1
		7	201	1	15	0	0	0	1
		8	200	1	15	0	0	0	1
		9	200	0	15	0	0	0	1
		10	175	25	15	0	0	0	1
		11	175	0	15	0	0	0	1
		12	174	1	15	0	0	0	1
	2015	1	174	0	15	0	0	0	1
		2	165	9	15	0	0	0	1
		3	165	0	15	0	0	0	1
		4	164	1	15	0	0	0	1
		5	164	0	15	0	0	0	1
		6	153	11	15	0	0	0	1
		7	147	6	15	0	0	0	1
		8	147	0	15	0	0	0	1
		9	147	0	15	0	0	0	1
		10	122	25	15	0	0	0	1
		11	122	0	15	0	0	0	1
		12	101	21	15	0	0	0	1

Table 4.6 and Table 4.7 above show the value of demand, supply and number of orders for each month. Table 4.8 below may exhibit the changes on value of s and S and the impacts the have on the actual service level and the total cost. We select only those achieving service level of more than 95%.

Table 4.8 Variation value s, S, Service Level and Total Cost Material Pump Parts

s	S	Total Order	Order Cost	Total Inventory	Holding Cost	Unit Price	Total Cost	Z value	SL
6	9	69	$35	8282	$566	$2,832	$4,692,613	50.00%	99.82%
9	12	73	$35	8250	$566	$2,832	$4,674,631	61.03%	99.82%
12	15	76	$35	8271	$566	$2,832	$4,686,628	71.23%	99.82%
15	18	79	$35	8295	$566	$2,832	$4,700,325	81.06%	99.82%
19	22	83	$35	8339	$566	$2,832	$4,725,383	90.66%	99.82%
23	26	87	$35	8390	$566	$2,832	$4,754,404	95.35%	99.82%
27	30	91	$35	8450	$566	$2,832	$4,788,523	98.12%	99.82%
41	44	105	$35	8689	$566	$2,832	$4,924,362	99.97%	99.83%

From Table 4.10 can be seen the simulation results by changing values of Z value with the range from 50% up to 99.97%, will lead to some variations of the s and S value that will lead to lower total cost and service level that meets or exceed with the target. A line indicated by yellow color is the result from formulation of s and S Max calculation, while the blue color is the result of the alternative simulation's calculation that was performed by Minitab software.

4.3 Analysis of Results

Analyzes perform in this research taken 2 samples from 5 materials type which one has been classified as the intermittent with lumpy and the other categories as erractic demand material category.

4.3.1 Pump Parts

Pump Parts material is classified as intermittent lumpy demand category, since it has a zero demand pattern for a long time. From table 4.8 and table 4.9, the simulation results of this material can be seen. By simulating materials with variations of s and S values for 60 months we can see the total number of orders, total inventory which later can be converted into the value of total cost as in Table 4.10.

Table 4.9 shows the results of the difference of s, S formulation and s, S alternatives.

Table 4.9 Difference Formulation and Alternative Materials Pump Parts

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	23	26	87	8390	$4,754,404	99.82%
Simulation	6	9	69	8282	$4,692,613	99.82%
	9	12	73	8250	$4,674,631	99.82%
	12	15	76	8271	$4,686,628	99.82%

Table 4.9 shows the comparison result between the s and S obtained from the formulation (which assumes that demand is normally distributed) and the solutions obtained from simulation. The formulation calculation demonstrates higher total cost compared to the alternative solution obtained from simulation. All of the service level are high (beyond the company target) by 99.82% because most of the materials are in stock. From the simulation, there are 3 options may be choosen to get the lowest total cost since the service level are not an issue anymore. Align with the purposes of this research; the alternatives that will be chosen are the lowest total cost which service level meet or exceed 95%.

The chosen options is from the second alternative with the value of s is 9 pieces; value of S is 12 pieces that produce a total cost of USD 4,674,631. The lowest total cost among other alternatives and the service level is 99.82%.

4.3.2 Instrumentation Parts

Instrumentation Parts materials included as intermittent with erractic demand category that can be seen from table 4.4. With the same method for the simulation results obtained 60 months shown in Table 4.10 and Table 4.13. Indicate in the table below just 30 months out of 60 months data.

Table 4.10 Examples of Simulation Results of Instrument Parts material Calculated with Formula s, S

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	1294	7	106	8	8	0	1
		2	1293	5	106	4	4	0	1
		3	1212	94	106	14	13	0	1
		4	1142	83	106	13	13	0	1
		5	1164	23	106	45	45	0	1
		6	1134	36	106	31	6	0	1
		7	1228	13	106	82	107	0	1
		8	1198	51	106	20	21	0	1
		9	1204	11	106	17	17	0	1
		10	1188	24	106	8	8	0	1
		11	1127	77	106	18	16	0	1
		12	1123	22	106	16	18	0	1
	2011	1	1101	33	106	12	11	0	1
		2	1108	7	106	13	14	0	1
		3	1064	67	106	26	23	0	1
		4	1112	14	106	59	62	0	1
		5	1074	70	106	32	32	0	1
		6	1047	43	106	16	16	0	1
		7	1058	2	106	14	13	0	1
		8	1082	1	106	24	25	0	1
		9	1066	33	106	17	17	0	1
		10	1061	7	106	2	2	0	1
		11	1029	38	106	6	6	0	1
		12	1016	13	106	0	0	0	1
	2012	1	966	65	106	15	15	0	1
		2	898	78	106	10	10	0	1
		3	826	75	106	3	3	0	1
		4	833	3	106	10	10	0	1
		5	835	14	106	41	16	0	1
		6	858	5	106	3	28	0	1
		7	888	41	106	71	71	0	1
		8	851	42	106	5	5	0	1
		9	832	19	106	0	0	0	1
		10	833	6	106	7	7	0	1
		11	842	2	106	11	11	0	1
		12	827	15	106	1	1	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	744	83	106	0	0	0	1
		2	722	22	106	0	0	0	1
		3	715	7	106	0	0	0	1
		4	709	6	106	0	0	0	1
		5	696	13	106	0	0	0	1
		6	683	13	106	0	0	0	1
		7	647	36	106	0	0	0	1
		8	572	75	106	0	0	0	1
		9	561	11	106	0	0	0	1
		10	478	83	106	0	0	0	1
		11	403	75	106	0	0	0	1
		12	384	19	106	0	0	0	1
	2014	1	301	83	106	0	0	0	1
		2	265	36	106	0	0	0	1
		3	254	11	106	0	0	0	1
		4	179	75	106	0	0	0	1
		5	166	13	106	0	0	0	1
		6	72	94	106	34	0	0	1
		7	23	83	106	83	34	0	1
		8	103	3	106	3	83	0	1
		9	93	13	106	13	3	0	1
		10	92	14	106	14	13	0	1
		11	55	51	106	51	14	0	1
		12	29	77	106	77	51	0	1
	2015	1	73	33	106	33	77	0	1
		2	92	14	106	14	33	0	1
		3	87	19	106	19	14	0	1
		4	68	38	106	38	19	0	1
		5	82	24	106	24	38	0	1
		6	63	43	106	43	24	0	1
		7	93	13	106	13	43	0	1
		8	39	67	106	67	13	0	1
		9	99	7	106	7	67	0	1
		10	29	77	106	77	7	0	1
		11	100	6	106	6	77	0	1
		12	104	2	106	2	6	0	1

Table 4.11 Simulation Result Example for material Instrument Parts from s, S Simulation

	Year	Month	Inventory	Demand	S Simulation	Order	Receipt	On Order	L
Existing	2010	1	1294	7	74	8	8	0	1
		2	1293	5	74	4	4	0	1
		3	1212	94	74	14	13	0	1
		4	1142	83	74	13	13	0	1
		5	1164	23	74	45	45	0	1
		6	1134	36	74	31	6	0	1
		7	1228	13	74	82	107	0	1
		8	1198	51	74	20	21	0	1
		9	1204	11	74	17	17	0	1
		10	1188	24	74	8	8	0	1
		11	1127	77	74	18	16	0	1
		12	1123	22	74	16	18	0	1
	2011	1	1101	33	74	12	11	0	1
		2	1108	7	74	13	14	0	1
		3	1064	67	74	26	23	0	1
		4	1112	14	74	59	62	0	1
		5	1074	70	74	32	32	0	1
		6	1047	43	74	16	16	0	1
		7	1058	2	74	14	13	0	1
		8	1082	1	74	24	25	0	1
		9	1066	33	74	17	17	0	1
		10	1061	7	74	2	2	0	1
		11	1029	38	74	6	6	0	1
		12	1016	13	74	0	0	0	1
	2012	1	966	65	74	15	15	0	1
		2	898	78	74	10	10	0	1
		3	826	75	74	3	3	0	1
		4	833	3	74	10	10	0	1
		5	835	14	74	41	16	0	1
		6	858	5	74	3	28	0	1
		7	888	41	74	71	71	0	1
		8	851	42	74	5	5	0	1
		9	832	19	74	0	0	0	1
		10	833	6	74	7	7	0	1
		11	842	2	74	11	11	0	1
		12	827	15	74	1	1	0	1

	Year	Month	Inventory	Demand	S Simulation	Order	Receipt	On Order	L
Forecasting	2013	1	744	83	74	0	0	0	1
		2	722	22	74	0	0	0	1
		3	715	7	74	0	0	0	1
		4	709	6	74	0	0	0	1
		5	696	13	74	0	0	0	1
		6	683	13	74	0	0	0	1
		7	647	36	74	0	0	0	1
		8	572	75	74	0	0	0	1
		9	561	11	74	0	0	0	1
		10	478	83	74	0	0	0	1
		11	403	75	74	0	0	0	1
		12	384	19	74	0	0	0	1
	2014	1	301	83	74	0	0	0	1
		2	265	36	74	0	0	0	1
		3	254	11	74	0	0	0	1
		4	179	75	74	0	0	0	1
		5	166	13	74	0	0	0	1
		6	72	94	74	2	0	0	1
		7	-9	83	74	83	2	0	1
		8	71	3	74	3	83	0	1
		9	61	13	74	13	3	0	1
		10	60	14	74	14	13	0	1
		11	23	51	74	51	14	0	1
		12	-3	77	74	77	51	0	1
	2015	1	41	33	74	33	77	0	1
		2	60	14	74	14	33	0	1
		3	55	19	74	19	14	0	1
		4	36	38	74	38	19	0	1
		5	50	24	74	24	38	0	1
		6	31	43	74	43	24	0	1
		7	61	13	74	13	43	0	1
		8	7	67	74	67	13	0	1
		9	67	7	74	7	67	0	1
		10	-3	77	74	77	7	0	1
		11	68	6	74	6	77	0	1
		12	72	2	74	2	6	0	1

Table 4.10 and Table 4.11 above are shown the value of demand, supply and number of orders for each month. Table 4.12 below show the changes of the s and S values that the actual service level equal or exceed 95%.

Table 4.12 Difference Formulation and Simulation Materials Instrumentation Parts

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	82	106	1332	11705	$ 631,870	98.98%
Simulation	34	58	1284	9703	$ 530,090	98.77%
	42	66	1292	10031	$ 546,770	98.81%
	50	74	1300	10361	$ 563,550	98.84%

Looking at table From Table 4.12 above can be analyzed that with the formulation and targetted service level of meet or exceed 95%, may obtain a low cost value. Both of the formulation and alternatives simulation have resulted an exceed service level target in their four alternatives option. The first alternative is from the formulation where s value is 82 units; S is 106 units resulted in a total cost of USD. 631,870 with a service level of 98.98%, with the second alternative s value of 34 units, S 58 units, produces a total cost of USD 530,090 with service level of 98.77%, a third alternative is the s value of 42 units, S value 66 units, resulted in a total cost of USD 546,770 with 98.81% service level. And the last alternative is the s value of 50 units, S 74 units, produces a total cost of USD 563,550 with service level of 98.84%.

The choice taken is the second alternative; due to the lowest total cost among others and has exceeded the service level target.

Tables 4.13 will show a comparison of formulation and simulation results for all of the materials.

Table 4.13 Comparison Formulation and Simulation of All Materials

No	Material	s, S from Formula				s, S from Simulation				Inv.Var.	SL Var.
		s	S	Total Inv. Cost	SL	s	S	Total Inv. Cost	SL		
1	Instrumentation Parts (14)	82	106	631,870	98.98%	34	58	530,090	98.77%	16.1%	0.22%
2	Electrical Parts (51)	166	208	14,564,566	99.95%	73	115	14,564,566	99.95%	0.0%	0.00%
3	Valve Parts (66)	100	112	7,126,450	99.89%	24	36	7,126,450	99.89%	0.0%	0.00%
4	Pump Parts (76)	23	26	4,754,404	99.82%	9	12	4,674,631	99.82%	1.7%	0.00%
5	Turbine Hardware Parts (78)	1576	1694	17,703,466	99.92%	401	519	17,674,276	99.92%	0.2%	0.00%
									Average	3.6%	0.04%

Table 4.13 shows that the result from formula calculated with Z value inputted by 95% does not always achieved actual service level of 95%, but could be more or less than that. And the results of the formula calculated does not always achieve a lower total cost compare to s, S simulation calculation. Table 4.13 shows that from the average variance between the total cost and service level between s, S formula and the s, S alternative will lead to significant reduced in material's total cost by 3.6%. The materials service level has been reduced slightly by 0.04% but still exceed the company service level of 95%.

Table 4.14 Comparison Existing and Decision Taken of All Materials

No	Material	Existing Condition				s, S Decision				Inv. Var	SL Var.
		s	S	Total Inv. Cost	Saving	s	S	Total Inv. Cost	SL		
1	Instrumentation Parts (a)	78	101	$ 631,430	99.69%	50	74	$ 112,710	98.84%	82%	0.86%
2	Electrical Parts (b)	188	233	$ 3,721,869	99.96%	166	208	$ 2,912,913	99.95%	22%	0.01%
3	Valve Parts (c)	96	116	$ 1,891,782	99.92%	100	112	$ 1,425,290	99.89%	25%	0.03%
4	Pump Parts (d)	23	26	$ 1,868,961	99.91%	23	26	$ 950,881	99.82%	49%	0.09%
5	Turbine Hardware Parts (c)	1351	1450	$ 8,979,680	99.97%	1576	1694	$ 3,540,693	99.92%	61%	0.05%
									Average	48%	0.21%

Table 4.14 shows a comparison of esixting historical situation and decision results for all of the materials. Table 4.14 shows that the result from decision point on s and S max value will lead to significant reduced in material's total inventory cost by 48% from the existing situation. The materials service level has been slightly reduced by 0.21% but still exceed the company service level of 95%.

Variance in total cost and the service level between formulation and simulation can also be summarized in below Figure 4.3, a quadrant differences between the total cost and the difference in service level.

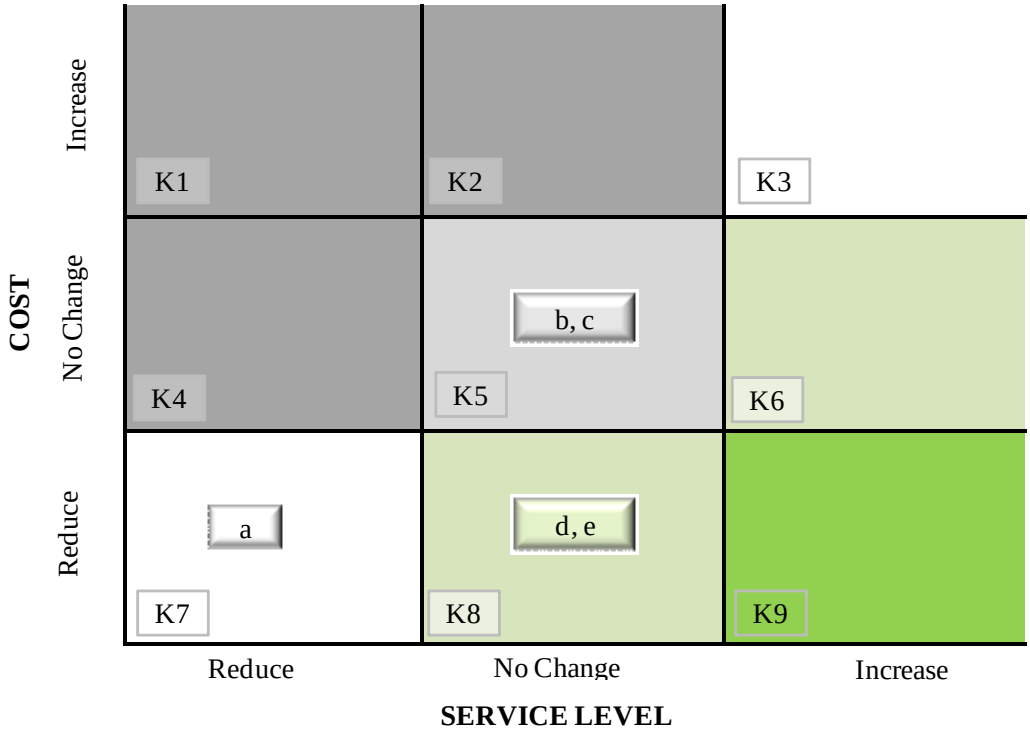

Figure 4.7 Total Cost Difference Quadrants and Service Level

From Figure 4.7 there are nine quadrants where most of the materials expected to be in quadrant K9 and is also expected to be in quadrant K6 and K8 and is not expected to be in quadrant K1, K2, and K4. Quadrant K5 is still within tolerance. K7 is acceptable depends on company sevice level target, since the total cost is reduced but the service level also reduced. These are comparing between formulation and alternative result. If the formulation is lower than the alternative result, but the formulation itself has exceeded the service level of the company target, so the K7 quadarant is also acceptable. From Table 4.20 it can be seen that from the 5 materials, there are 2 materials in K8 quadrant, 2 materials in K5 quadrant, and 1 material in quadrant K7. Dominant material is widely available in the quadrant K8 meaning that total cost is reduced but service level remains the same. Material in this quadrant is material where the value of s and S alternative

has provided the expected total cost which has reduced from the s and S formula. Then, the value changes need to be done in Z value input to obtain the expected s and S Max value to achieve the most efficient total cost and meets or exceed service level target.

There are 2 materials in quadrant K5 quadrant. It indicates that there is no difference between the results formulation and alternatives. Due to the value of the initial inventory is too large so there is no reservation (order) being made.

Last is 1 material filled in K7 quadrant, means the total cost reduce, service level also reduce but is still acceptable since it is beyond the company service level target (95%). This happens because the number of existing inventories are too big on the materials that have impacted the total cost so by doing a simulations will be obtained the orders and inventory level that are appropriate, meet the demand so the total cost can be reduced but still maintain an expected service level

Overall, the research shows that from the average variance between the total cost and service level between s, S formula and the s, S simulation will lead to significant reduced in material's total cost by 3.6%. The materials service level has been reduced slightly by 0.04% but still exceed the company service level of 95%. And it has improved the inventory cost by % and service level by % from the existing situation.

CHAPTER V

CONCLUSIONS AND SUGGESTIONS

From analysis and discussion in the previous chapter, it can be put forward the following conclusions and suggestions.

5.1 Conclusions

The conclusions that can be drawn from this study are:

1. Material classification resulted that most of materials are included in the characteristic of intermittent with erractic and lumpy demand category. This is in accordance with materials character which constitute the majority of spare parts or materials required to meet maintenance and repair needs.
2. Simulation results indicate that the value of (s, S) obtained from the formula does not always provide the best service level and total cost. With increase or the value of Z value inputted to an interval range, most of the new s and S values improved the service levels and / or the total cost.
3. Experiments to obtain the values of s and S have produced the best average reduction of the materials total cost by 3.6% compared to those obtained from the formula. The materials service level has been reduced slightly by 0.04% but still exceed the company service level of 95%. Overall the company total cost is reduced with an improvement in the service level as well (beyond the company targetted level). And it has improved the inventory cost by % and service level by % from the existing situation.
4. The result from decision on s and S max value will lead to significant reduced in material's total inventory cost by 48% from the existing situation. The materials service level has been slightly reduced by 0.21% but still exceed the company service level of 95%

5.2 Suggestions

The suggestions that can be considered for the next research are:

1. Current research uses a constant lead time material characteristic, whereby is 1 month. It is suggested to consider more varieties lead time that suit to the materials characteristic.
2. Inventory control is done by various methods in accordance with characteristics of each material.
3. More diversified materials to be studied, not only turbine parts but can be other equipment that support the power plant operation such as HRSG (Heat Recovery Steam Generator) parts, to have the optimum improvement in reduced overall company's total cost and increased the service level.

APPENDIXES

Appendix 1 Pump Parts Detail Calculation

Table 1.1 Random Number

Demand	Frequency	Proportion	Cum. Proportion	Interval Proportion
0	12	0.333	0.333	0.000 - 0.333
1	9	0.250	0.583	0.334 - 0.583
2	1	0.028	0.611	0.584 - 0.611
4	2	0.056	0.667	0.612 - 0.667
5	1	0.028	0.694	0.668 - 0.694
6	2	0.056	0.750	0.695 - 0.750
8	1	0.028	0.778	0.751 - 0.778
9	1	0.028	0.806	0.779 - 0.806
11	1	0.028	0.833	0.807 - 0.833
12	1	0.028	0.861	0.834 - 0.861
21	1	0.028	0.889	0.862 - 0.889
23	1	0.028	0.917	0.890 - 0.917
25	1	0.028	0.944	0.918 - 0.944
26	1	0.028	0.972	0.945 - 0.972
45	1	0.028	1.000	0.973 - 1.000
0	12	0.333	0.333	0.000 - 0.333
1	9	0.250	0.583	0.334 - 0.583
2	1	0.028	0.611	0.584 - 0.611

Table 1.2 Forecasted Demand

Generate Random	Demand
0.725	6
0.087	0
0.454	1
0.527	1
0.052	0
0.111	0
0.546	1
0.727	6
0.233	0
0.081	0
0.080	0
0.027	0
0.753	8
0.636	4
0.980	45
0.765	8
0.735	6
0.408	1
0.373	1
0.354	1
0.218	0
0.930	25
0.274	0
0.437	1
0.157	0
0.789	9
0.194	0
0.372	1
0.233	0
0.815	11
0.707	6
0.074	0
0.045	0
0.937	25
0.165	0
0.878	21
0.604	2
0.485	1
0.966	26
0.898	23
0.837	12
0.195	0

Generate Random	Demand
0.044	0
0.412	1
0.827	11
0.358	1
0.061	0
0.271	0
0.721	6
0.575	1
0.018	0
0.246	0
0.845	12
0.092	0
0.086	0
0.238	0
0.989	45
0.887	21
0.109	0
0.302	0
0.725	6

Table 1.3 s, S Formulation

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	234	1	26	0	0	0	1
		2	255	1	26	22	22	0	1
		3	255	1	26	1	1	0	1
		4	256	0	26	1	1	0	1
		5	256	4	26	4	4	0	1
		6	230	26	26	0	0	0	1
		7	274	0	26	44	44	0	1
		8	274	0	26	0	0	0	1
		9	261	45	26	32	32	0	1
		10	260	1	26	0	0	0	1
		11	256	5	26	1	1	0	1
		12	232	25	26	1	1	0	1
	2011	1	236	1	26	5	5	0	1
		2	213	23	26	0	0	0	1
		3	235	8	26	30	30	0	1
		4	270	21	26	56	56	0	1
		5	269	1	26	0	0	0	1
		6	277	6	26	14	14	0	1
		7	274	12	26	9	9	0	1
		8	266	9	26	1	1	0	1
		9	278	0	26	12	12	0	1
		10	303	1	26	26	26	0	1
		11	306	2	26	5	5	0	1
		12	307	0	26	1	1	0	1
	2012	1	307	0	26	0	0	0	1
		2	301	6	26	0	0	0	1
		3	300	1	26	0	0	0	1
		4	300	0	26	0	0	0	1
		5	301	0	26	1	1	0	1
		6	301	0	26	0	0	0	1
		7	301	0	26	0	0	0	1
		8	301	0	26	0	0	0	1
		9	304	0	26	3	3	0	1
		10	303	1	26	0	0	0	1
		11	299	4	26	0	0	0	1
		12	289	11	26	1	1	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	283	6	26	0	0	0	1
		2	283	0	26	0	0	0	1
		3	282	1	26	0	0	0	1
		4	281	1	26	0	0	0	1
		5	281	0	26	0	0	0	1
		6	281	0	26	0	0	0	1
		7	280	1	26	0	0	0	1
		8	274	6	26	0	0	0	1
		9	274	0	26	0	0	0	1
		10	274	0	26	0	0	0	1
		11	274	0	26	0	0	0	1
		12	274	0	26	0	0	0	1
	2014	1	266	8	26	0	0	0	1
		2	262	4	26	0	0	0	1
		3	217	45	26	0	0	0	1
		4	209	8	26	0	0	0	1
		5	203	6	26	0	0	0	1
		6	202	1	26	0	0	0	1
		7	201	1	26	0	0	0	1
		8	200	1	26	0	0	0	1
		9	200	0	26	0	0	0	1
		10	175	25	26	0	0	0	1
		11	175	0	26	0	0	0	1
		12	174	1	26	0	0	0	1
	2015	1	174	0	26	0	0	0	1
		2	165	9	26	0	0	0	1
		3	165	0	26	0	0	0	1
		4	164	1	26	0	0	0	1
		5	164	0	26	0	0	0	1
		6	153	11	26	0	0	0	1
		7	147	6	26	0	0	0	1
		8	147	0	26	0	0	0	1
		9	147	0	26	0	0	0	1
		10	122	25	26	0	0	0	1
		11	122	0	26	0	0	0	1
		12	101	21	26	0	0	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2016	1	99	2	26	0	0	0	1
		2	98	1	26	0	0	0	1
		3	72	26	26	0	0	0	1
		4	49	23	26	0	0	0	1
		5	37	12	26	0	0	0	1
		6	37	0	26	0	0	0	1
		7	37	0	26	0	0	0	1
		8	36	1	26	0	0	0	1
		9	25	11	26	1	0	0	1
		10	25	1	26	1	1	0	1
		11	26	0	26	0	1	0	1
		12	26	0	26	0	0	0	1
	2017	1	20	6	26	6	0	0	1
		2	25	1	26	1	6	0	1
		3	26	0	26	0	1	0	1
		4	26	0	26	0	0	0	1
		5	14	12	26	12	0	0	1
		6	26	0	26	0	12	0	1
		7	26	0	26	0	0	0	1
		8	26	0	26	0	0	0	1
		9	-19	45	26	45	0	0	1
		10	5	21	26	21	45	0	1
		11	26	0	26	0	21	0	1
		12	26	0	26	0	0	0	1

Table 1.4 s, S Simulation

Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
2010	1	1	234	1	15	0	0	0
	2	2	255	1	15	22	22	0
	3	3	255	1	15	1	1	0
	4	4	256	0	15	1	1	0
	5	5	256	4	15	4	4	0
	6	6	230	26	15	0	0	0
	7	7	274	0	15	44	44	0
	8	8	274	0	15	0	0	0
	9	9	261	45	15	32	32	0
	10	10	260	1	15	0	0	0
	11	11	256	5	15	1	1	0
	12	12	232	25	15	1	1	0
2011	1	1	236	1	15	5	5	0
	2	2	213	23	15	0	0	0
	3	3	235	8	15	30	30	0
	4	4	270	21	15	56	56	0
	5	5	269	1	15	0	0	0
	6	6	277	6	15	14	14	0
	7	7	274	12	15	9	9	0
	8	8	266	9	15	1	1	0
	9	9	278	0	15	12	12	0
	10	10	303	1	15	26	26	0
	11	11	306	2	15	5	5	0
	12	12	307	0	15	1	1	0
2012	1	1	307	0	15	0	0	0
	2	2	301	6	15	0	0	0
	3	3	300	1	15	0	0	0
	4	4	300	0	15	0	0	0
	5	5	301	0	15	1	1	0
	6	6	301	0	15	0	0	0
	7	7	301	0	15	0	0	0
	8	8	301	0	15	0	0	0
	9	9	304	0	15	3	3	0
	10	10	303	1	15	0	0	0
	11	11	299	4	15	0	0	0
	12	12	289	11	15	1	1	0

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Forecasting	2013	1	283	6	15	0	0	0	1
		2	283	0	15	0	0	0	1
		3	282	1	15	0	0	0	1
		4	281	1	15	0	0	0	1
		5	281	0	15	0	0	0	1
		6	281	0	15	0	0	0	1
		7	280	1	15	0	0	0	1
		8	274	6	15	0	0	0	1
		9	274	0	15	0	0	0	1
		10	274	0	15	0	0	0	1
		11	274	0	15	0	0	0	1
		12	274	0	15	0	0	0	1
	2014	1	266	8	15	0	0	0	1
		2	262	4	15	0	0	0	1
		3	217	45	15	0	0	0	1
		4	209	8	15	0	0	0	1
		5	203	6	15	0	0	0	1
		6	202	1	15	0	0	0	1
		7	201	1	15	0	0	0	1
		8	200	1	15	0	0	0	1
		9	200	0	15	0	0	0	1
		10	175	25	15	0	0	0	1
		11	175	0	15	0	0	0	1
		12	174	1	15	0	0	0	1
	2015	1	174	0	15	0	0	0	1
		2	165	9	15	0	0	0	1
		3	165	0	15	0	0	0	1
		4	164	1	15	0	0	0	1
		5	164	0	15	0	0	0	1
		6	153	11	15	0	0	0	1
		7	147	6	15	0	0	0	1
		8	147	0	15	0	0	0	1
		9	147	0	15	0	0	0	1
		10	122	25	15	0	0	0	1
		11	122	0	15	0	0	0	1
		12	101	21	15	0	0	0	1

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Forecasting	2016	1	99	2	15	0	0	0	1
		2	98	1	15	0	0	0	1
		3	72	26	15	0	0	0	1
		4	49	23	15	0	0	0	1
		5	37	12	15	0	0	0	1
		6	37	0	15	0	0	0	1
		7	37	0	15	0	0	0	1
		8	36	1	15	0	0	0	1
		9	25	11	15	0	0	0	1
		10	24	1	15	0	0	0	1
		11	24	0	15	0	0	0	1
		12	24	0	15	0	0	0	1
	2017	1	18	6	15	0	0	0	1
		2	17	1	15	0	0	0	1
		3	17	0	15	0	0	0	1
		4	17	0	15	0	0	0	1
		5	5	12	15	10	0	0	1
		6	15	0	15	0	10	0	1
		7	15	0	15	0	0	0	1
		8	15	0	15	0	0	0	1
		9	-30	45	15	45	0	0	1
		10	-6	21	15	21	45	0	1
		11	15	0	15	0	21	0	1
		12	15	0	15	0	0	0	1

Table 1.5 Comparisons

s	S	Total Order	Order Cost	Total Inventory	Holding Cost	Unit Price	Total Cost	Z value	SL
6	9	69	$35	8282	$566	$2,832	$4,692,613	50.00%	99.82%
9	12	73	$35	8250	$566	$2,832	$4,674,631	61.03%	99.82%
12	15	76	$35	8271	$566	$2,832	$4,686,628	71.23%	99.82%
15	18	79	$35	8295	$566	$2,832	$4,700,325	81.06%	99.82%
19	22	83	$35	8339	$566	$2,832	$4,725,383	90.66%	99.82%
23	26	87	$35	8390	$566	$2,832	$4,754,404	95.35%	99.82%
27	30	91	$35	8450	$566	$2,832	$4,788,523	98.12%	99.82%
41	44	105	$35	8689	$566	$2,832	$4,924,362	99.97%	99.83%

Table 1.6 Options

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	23	26	87	8390	$4,754,404	99.82%
Simulation	6	9	69	8282	$4,692,613	99.82%
	9	12	73	8250	$4,674,631	99.82%
	12	15	76	8271	$4,686,628	99.82%

Appendix 2 Instrument Parts Detail Calculation

Table 2.1 Random Number

Demand	Frequency	Proportion	Cum. Proportion	Interval Proportion
1	1	0.028	0.028	0.000 - 0.028
2	2	0.056	0.083	0.029 - 0.083
3	1	0.028	0.111	0.084 - 0.111
5	2	0.056	0.167	0.112 - 0.167
6	1	0.028	0.194	0.168 - 0.194
7	3	0.083	0.278	0.195 - 0.278
11	1	0.028	0.306	0.279 - 0.306
13	2	0.056	0.361	0.307 - 0.361
14	2	0.056	0.417	0.362 - 0.417
15	1	0.028	0.444	0.418 - 0.444
19	1	0.028	0.472	0.445 - 0.472
22	1	0.028	0.500	0.473 - 0.500
23	1	0.028	0.528	0.501 - 0.528
24	1	0.028	0.556	0.529 - 0.556
33	2	0.056	0.611	0.557 - 0.611
36	1	0.028	0.639	0.612 - 0.639
38	1	0.028	0.667	0.640 - 0.667
41	1	0.028	0.694	0.668 - 0.694
42	1	0.028	0.722	0.695 - 0.722
43	1	0.028	0.750	0.723 - 0.750
51	1	0.028	0.778	0.751 - 0.778
65	1	0.028	0.806	0.779 - 0.806
67	1	0.028	0.833	0.807 - 0.833
70	1	0.028	0.861	0.834 - 0.861
75	1	0.028	0.889	0.862 - 0.889
77	1	0.028	0.917	0.890 - 0.917
78	1	0.028	0.944	0.918 - 0.944
83	1	0.028	0.972	0.945 - 0.972
94	1	0.028	1.000	0.973 - 1.000

Table 2.2 Forecasted Demand

Generate Random	Demand
0.948	83
0.479	22
0.259	7
0.176	6
0.344	13
0.327	13
0.627	36
0.873	75
0.287	11
0.964	83
0.866	75
0.468	19
0.958	83
0.627	36
0.287	11
0.883	75
0.312	13
0.996	94
0.952	83
0.103	3
0.329	13
0.365	14
0.750	51
0.894	77
0.567	33
0.392	14
0.470	19
0.653	38
0.545	24
0.730	43
0.349	13
0.824	67
0.201	7
0.897	77
0.180	6
0.072	2
0.715	42
0.255	7
0.484	22
0.803	65

Generate Random	Demand
0.496	22
0.641	38
0.576	33
0.001	1
0.626	36
0.235	7
0.723	43
0.107	3
0.884	75
0.383	14
0.221	7
0.585	33
0.003	1
0.287	11
0.310	13
0.168	6
0.632	36
0.963	83
0.586	33
0.958	83
0.948	83
0.479	22
0.259	7

Table 2.3 s, S Formulation

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	1294	7	106	8	8	0	1
		2	1293	5	106	4	4	0	1
		3	1212	94	106	14	13	0	1
		4	1142	83	106	13	13	0	1
		5	1164	23	106	45	45	0	1
		6	1134	36	106	31	6	0	1
		7	1228	13	106	82	107	0	1
		8	1198	51	106	20	21	0	1
		9	1204	11	106	17	17	0	1
		10	1188	24	106	8	8	0	1
		11	1127	77	106	18	16	0	1
		12	1123	22	106	16	18	0	1
	2011	1	1101	33	106	12	11	0	1
		2	1108	7	106	13	14	0	1
		3	1064	67	106	26	23	0	1
		4	1112	14	106	59	62	0	1
		5	1074	70	106	32	32	0	1
		6	1047	43	106	16	16	0	1
		7	1058	2	106	14	13	0	1
		8	1082	1	106	24	25	0	1
		9	1066	33	106	17	17	0	1
		10	1061	7	106	2	2	0	1
		11	1029	38	106	6	6	0	1
		12	1016	13	106	0	0	0	1
	2012	1	966	65	106	15	15	0	1
		2	898	78	106	10	10	0	1
		3	826	75	106	3	3	0	1
		4	833	3	106	10	10	0	1
		5	835	14	106	41	16	0	1
		6	858	5	106	3	28	0	1
		7	888	41	106	71	71	0	1
		8	851	42	106	5	5	0	1
		9	832	19	106	0	0	0	1
		10	833	6	106	7	7	0	1
		11	842	2	106	11	11	0	1
		12	827	15	106	1	1	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	744	83	106	0	0	0	1
		2	722	22	106	0	0	0	1
		3	715	7	106	0	0	0	1
		4	709	6	106	0	0	0	1
		5	696	13	106	0	0	0	1
		6	683	13	106	0	0	0	1
		7	647	36	106	0	0	0	1
		8	572	75	106	0	0	0	1
		9	561	11	106	0	0	0	1
		10	478	83	106	0	0	0	1
		11	403	75	106	0	0	0	1
		12	384	19	106	0	0	0	1
	2014	1	301	83	106	0	0	0	1
		2	265	36	106	0	0	0	1
		3	254	11	106	0	0	0	1
		4	179	75	106	0	0	0	1
		5	166	13	106	0	0	0	1
		6	72	94	106	34	0	0	1
		7	23	83	106	83	34	0	1
		8	103	3	106	3	83	0	1
		9	93	13	106	13	3	0	1
		10	92	14	106	14	13	0	1
		11	55	51	106	51	14	0	1
		12	29	77	106	77	51	0	1
	2015	1	73	33	106	33	77	0	1
		2	92	14	106	14	33	0	1
		3	87	19	106	19	14	0	1
		4	68	38	106	38	19	0	1
		5	82	24	106	24	38	0	1
		6	63	43	106	43	24	0	1
		7	93	13	106	13	43	0	1
		8	39	67	106	67	13	0	1
		9	99	7	106	7	67	0	1
		10	29	77	106	77	7	0	1
		11	100	6	106	6	77	0	1
		12	104	2	106	2	6	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2016	1	64	42	106	42	2	0	1
		2	99	7	106	7	42	0	1
		3	84	22	106	22	7	0	1
		4	41	65	106	65	22	0	1
		5	84	22	106	22	65	0	1
		6	68	38	106	38	22	0	1
		7	73	33	106	33	38	0	1
		8	105	1	106	1	33	0	1
		9	70	36	106	36	1	0	1
		10	99	7	106	7	36	0	1
		11	63	43	106	43	7	0	1
		12	103	3	106	3	43	0	1
	2017	1	31	75	106	75	3	0	1
		2	92	14	106	14	75	0	1
		3	99	7	106	7	14	0	1
		4	73	33	106	33	7	0	1
		5	105	1	106	1	33	0	1
		6	95	11	106	11	1	0	1
		7	93	13	106	13	11	0	1
		8	100	6	106	6	13	0	1
		9	70	36	106	36	6	0	1
		10	23	83	106	83	36	0	1
		11	73	33	106	33	83	0	1
		12	23	83	106	83	33	0	1

Table 2.4 s, S Simulation

Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
2010	1	1294	7	74	8	8	0	1
	2	1293	5	74	4	4	0	1
	3	1212	94	74	14	13	0	1
	4	1142	83	74	13	13	0	1
	5	1164	23	74	45	45	0	1
	6	1134	36	74	31	6	0	1
	7	1228	13	74	82	107	0	1
	8	1198	51	74	20	21	0	1
	9	1204	11	74	17	17	0	1
	10	1188	24	74	8	8	0	1
	11	1127	77	74	18	16	0	1
	12	1123	22	74	16	18	0	1
2011	1	1101	33	74	12	11	0	1
	2	1108	7	74	13	14	0	1
	3	1064	67	74	26	23	0	1
	4	1112	14	74	59	62	0	1
	5	1074	70	74	32	32	0	1
	6	1047	43	74	16	16	0	1
	7	1058	2	74	14	13	0	1
	8	1082	1	74	24	25	0	1
	9	1066	33	74	17	17	0	1
	10	1061	7	74	2	2	0	1
	11	1029	38	74	6	6	0	1
	12	1016	13	74	0	0	0	1
2012	1	966	65	74	15	15	0	1
	2	898	78	74	10	10	0	1
	3	826	75	74	3	3	0	1
	4	833	3	74	10	10	0	1
	5	835	14	74	41	16	0	1
	6	858	5	74	3	28	0	1
	7	888	41	74	71	71	0	1
	8	851	42	74	5	5	0	1
	9	832	19	74	0	0	0	1
	10	833	6	74	7	7	0	1
	11	842	2	74	11	11	0	1
	12	827	15	74	1	1	0	1

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Forecasting	2013	1	744	83	74	0	0	0	1
		2	722	22	74	0	0	0	1
		3	715	7	74	0	0	0	1
		4	709	6	74	0	0	0	1
		5	696	13	74	0	0	0	1
		6	683	13	74	0	0	0	1
		7	647	36	74	0	0	0	1
		8	572	75	74	0	0	0	1
		9	561	11	74	0	0	0	1
		10	478	83	74	0	0	0	1
		11	403	75	74	0	0	0	1
		12	384	19	74	0	0	0	1
	2014	1	301	83	74	0	0	0	1
		2	265	36	74	0	0	0	1
		3	254	11	74	0	0	0	1
		4	179	75	74	0	0	0	1
		5	166	13	74	0	0	0	1
		6	72	94	74	2	0	0	1
		7	-9	83	74	83	2	0	1
		8	71	3	74	3	83	0	1
		9	61	13	74	13	3	0	1
		10	60	14	74	14	13	0	1
		11	23	51	74	51	14	0	1
		12	-3	77	74	77	51	0	1
	2015	1	41	33	74	33	77	0	1
		2	60	14	74	14	33	0	1
		3	55	19	74	19	14	0	1
		4	36	38	74	38	19	0	1
		5	50	24	74	24	38	0	1
		6	31	43	74	43	24	0	1
		7	61	13	74	13	43	0	1
		8	7	67	74	67	13	0	1
		9	67	7	74	7	67	0	1
		10	-3	77	74	77	7	0	1
		11	68	6	74	6	77	0	1
		12	72	2	74	2	6	0	1

	Year	Month	Inventory	Demand	S Alternative	Order	Receipt	On Order	L
Forecasting	2016	1	32	42	74	42	2	0	1
		2	67	7	74	7	42	0	1
		3	52	22	74	22	7	0	1
		4	9	65	74	65	22	0	1
		5	52	22	74	22	65	0	1
		6	36	38	74	38	22	0	1
		7	41	33	74	33	38	0	1
		8	73	1	74	1	33	0	1
		9	38	36	74	36	1	0	1
		10	67	7	74	7	36	0	1
		11	31	43	74	43	7	0	1
		12	71	3	74	3	43	0	1
	2017	1	-1	75	74	75	3	0	1
		2	60	14	74	14	75	0	1
		3	67	7	74	7	14	0	1
		4	41	33	74	33	7	0	1
		5	73	1	74	1	33	0	1
		6	63	11	74	11	1	0	1
		7	61	13	74	13	11	0	1
		8	68	6	74	6	13	0	1
		9	38	36	74	36	6	0	1
		10	-9	83	74	83	36	0	1
		11	41	33	74	33	83	0	1
		12	-9	83	74	83	33	0	1

Table 2.5 Comparisons

s	S	Total Order	Order Cost	Total Inventory	Holding Cost	Unit Price	Total Cost	Z value	SL
34	58	1284	$ 35	9703	$ 50	$ 250	$ 530,090	50.00%	98.77%
42	66	1292	$ 35	10031	$ 50	$ 250	$ 546,770	61.03%	98.81%
50	74	1300	$ 35	10361	$ 50	$ 250	$ 563,550	71.23%	98.84%
59	83	1309	$ 35	10739	$ 50	$ 250	$ 582,765	81.06%	98.88%
72	96	1322	$ 35	11285	$ 50	$ 250	$ 610,520	90.66%	98.94%
82	106	1332	$ 35	11705	$ 50	$ 250	$ 631,870	95.35%	98.98%
94	118	1344	$ 35	12209	$ 50	$ 250	$ 657,490	98.12%	99.02%
132	156	1382	$ 35	13805	$ 50	$ 250	$ 738,620	99.97%	99.13%

Table 2.6 Options

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	82	106	1332	11705	$ 631,870	98.98%
Simulation	34	58	1284	9703	$ 530,090	98.77%
	42	66	1292	10031	$ 546,770	98.81%
	50	74	1300	10361	$ 563,550	98.84%

Appendix 3 Electrical Parts Detail Calculation

Table 3.1 Random Number

Demand	Frequency	Proportion	Cum. Proportion	Interval Proportion
6	1	0.028	0.028	0.000 - 0.028
11	1	0.028	0.056	0.029 - 0.056
14	1	0.028	0.083	0.057 - 0.083
15	1	0.028	0.111	0.084 - 0.111
16	1	0.028	0.139	0.112 - 0.139
24	1	0.028	0.167	0.140 - 0.167
32	1	0.028	0.194	0.168 - 0.194
36	2	0.056	0.250	0.195 - 0.250
37	1	0.028	0.278	0.251 - 0.278
38	1	0.028	0.306	0.279 - 0.306
50	1	0.028	0.333	0.307 - 0.333
51	1	0.028	0.361	0.334 - 0.361
52	1	0.028	0.389	0.362 - 0.389
53	1	0.028	0.417	0.390 - 0.417
55	1	0.028	0.444	0.418 - 0.444
57	1	0.028	0.472	0.445 - 0.472
59	1	0.028	0.500	0.473 - 0.500
60	1	0.028	0.528	0.501 - 0.528
63	1	0.028	0.556	0.529 - 0.556
66	1	0.028	0.583	0.557 - 0.583
90	2	0.056	0.639	0.584 - 0.639
93	1	0.028	0.667	0.640 - 0.667
94	1	0.028	0.694	0.668 - 0.694
111	1	0.028	0.722	0.695 - 0.722
125	1	0.028	0.750	0.723 - 0.750
131	1	0.028	0.778	0.751 - 0.778
133	1	0.028	0.806	0.779 - 0.806
136	1	0.028	0.833	0.807 - 0.833
138	1	0.028	0.861	0.834 - 0.861
155	1	0.028	0.889	0.862 0.889
200	1	0.028	0.917	0.890 0.917
218	1	0.028	0.944	0.918 0.944
221	1	0.028	0.972	0.945 0.972
227	1	0.028	1.000	0.973 1.000

Table 3.2 Forecasted Demand

Generate Random	Demand
0.103	15
0.686	94
0.539	63
0.344	51
0.237	36
0.350	51
0.768	131
0.754	131
0.288	38
0.231	36
0.207	36
0.258	37
0.014	6
0.502	60
0.139	16
0.311	50
0.137	16
0.261	37
0.299	38
0.583	66
0.481	59
0.606	90
0.900	200
0.119	16
0.653	93
0.387	52
0.740	125
0.167	24
0.444	55
0.891	200
0.408	53
0.696	111
0.998	227
0.742	125
0.063	14
0.631	90
0.678	94
0.190	32
0.058	14
0.310	50

Generate Random	Demand
0.933	218
0.769	131
0.695	94
0.647	93
0.471	57
0.180	32
0.481	59
0.686	94
0.611	90
0.962	221
0.001	6
0.764	131
0.513	60
0.333	50
0.117	16
0.645	93
0.672	94
0.303	38
0.202	36
0.136	16
0.103	15
0.686	94
0.539	63

Table 3.3 s, S Formulation

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	8168	131	208	5	5	0	1
		2	8144	32	208	8	8	0	1
		3	7987	221	208	64	64	0	1
		4	7925	133	208	71	71	0	1
		5	7888	57	208	28	20	0	1
		6	7994	6	208	119	112	0	1
		7	7989	59	208	39	54	0	1
		8	7920	94	208	25	25	0	1
		9	7840	125	208	45	45	0	1
		10	7896	55	208	119	111	0	1
		11	7875	155	208	127	134	0	1
		12	7988	52	208	164	165	0	1
	2011	1	7903	90	208	10	5	0	1
		2	7890	36	208	18	23	0	1
		3	8140	93	208	344	343	0	1
		4	8167	24	208	50	51	0	1
		5	9948	90	208	1871	1871	0	1
		6	9734	227	208	13	13	0	1
		7	9686	66	208	18	18	0	1
		8	9679	16	208	9	9	0	1
		9	9569	138	208	28	28	0	1
		10	9509	63	208	3	3	0	1
		11	9608	15	208	114	114	0	1
		12	9524	111	208	27	27	0	1
	2012	1	9479	50	208	5	5	0	1
		2	9357	136	208	14	14	0	1
		3	9505	200	208	348	348	0	1
		4	9481	51	208	27	27	0	1
		5	9448	53	208	20	20	0	1
		6	9449	14	208	15	15	0	1
		7	9448	11	208	10	10	0	1
		8	9399	60	208	11	11	0	1
		9	9183	218	208	2	2	0	1
		10	9147	37	208	1	1	0	1
		11	9111	36	208	0	0	0	1
		12	9075	38	208	4	2	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	9060	15	208	0	0	0	1
		2	8966	94	208	0	0	0	1
		3	8903	63	208	0	0	0	1
		4	8852	51	208	0	0	0	1
		5	8816	36	208	0	0	0	1
		6	8765	51	208	0	0	0	1
		7	8634	131	208	0	0	0	1
		8	8503	131	208	0	0	0	1
		9	8465	38	208	0	0	0	1
		10	8429	36	208	0	0	0	1
		11	8393	36	208	0	0	0	1
		12	8356	37	208	0	0	0	1
	2014	1	8350	6	208	0	0	0	1
		2	8290	60	208	0	0	0	1
		3	8274	16	208	0	0	0	1
		4	8224	50	208	0	0	0	1
		5	8208	16	208	0	0	0	1
		6	8171	37	208	0	0	0	1
		7	8133	38	208	0	0	0	1
		8	8067	66	208	0	0	0	1
		9	8008	59	208	0	0	0	1
		10	7918	90	208	0	0	0	1
		11	7718	200	208	0	0	0	1
		12	7702	16	208	0	0	0	1
	2015	1	7609	93	208	0	0	0	1
		2	7557	52	208	0	0	0	1
		3	7432	125	208	0	0	0	1
		4	7408	24	208	0	0	0	1
		5	7353	55	208	0	0	0	1
		6	7153	200	208	0	0	0	1
		7	7100	53	208	0	0	0	1
		8	6989	111	208	0	0	0	1
		9	6762	227	208	0	0	0	1
		10	6637	125	208	0	0	0	1
		11	6623	14	208	0	0	0	1
		12	6533	90	208	0	0	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2016	1	6439	94	208	0	0	0	1
		2	6407	32	208	0	0	0	1
		3	6393	14	208	0	0	0	1
		4	6343	50	208	0	0	0	1
		5	6125	218	208	0	0	0	1
		6	5994	131	208	0	0	0	1
		7	5900	94	208	0	0	0	1
		8	5807	93	208	0	0	0	1
		9	5750	57	208	0	0	0	1
		10	5718	32	208	0	0	0	1
		11	5659	59	208	0	0	0	1
		12	5565	94	208	0	0	0	1
	2017	1	5475	90	208	0	0	0	1
		2	5254	221	208	0	0	0	1
		3	5248	6	208	0	0	0	1
		4	5117	131	208	0	0	0	1
		5	5057	60	208	0	0	0	1
		6	5007	50	208	0	0	0	1
		7	4991	16	208	0	0	0	1
		8	4898	93	208	0	0	0	1
		9	4804	94	208	0	0	0	1
		10	4766	38	208	0	0	0	1
		11	4730	36	208	0	0	0	1
		12	4714	16	208	0	0	0	1

Table 3.4 s, S Simulation

Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
2010	1	8168	131	146	5	5	0	1
	2	8144	32	146	8	8	0	1
	3	7987	221	146	64	64	0	1
	4	7925	133	146	71	71	0	1
	5	7888	57	146	28	20	0	1
	6	7994	6	146	119	112	0	1
	7	7989	59	146	39	54	0	1
	8	7920	94	146	25	25	0	1
	9	7840	125	146	45	45	0	1
	10	7896	55	146	119	111	0	1
	11	7875	155	146	127	134	0	1
	12	7988	52	146	164	165	0	1
2011	1	7903	90	146	10	5	0	1
	2	7890	36	146	18	23	0	1
	3	8140	93	146	344	343	0	1
	4	8167	24	146	50	51	0	1
	5	9948	90	146	1871	1871	0	1
	6	9734	227	146	13	13	0	1
	7	9686	66	146	18	18	0	1
	8	9679	16	146	9	9	0	1
	9	9569	138	146	28	28	0	1
	10	9509	63	146	3	3	0	1
	11	9608	15	146	114	114	0	1
	12	9524	111	146	27	27	0	1
2012	1	9479	50	146	5	5	0	1
	2	9357	136	146	14	14	0	1
	3	9505	200	146	348	348	0	1
	4	9481	51	146	27	27	0	1
	5	9448	53	146	20	20	0	1
	6	9449	14	146	15	15	0	1
	7	9448	11	146	10	10	0	1
	8	9399	60	146	11	11	0	1
	9	9183	218	146	2	2	0	1
	10	9147	37	146	1	1	0	1
	11	9111	36	146	0	0	0	1
	12	9075	38	146	4	2	0	1

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Forecasting	2013	1	9075	15	146	0	0	0	1
		2	8981	94	146	0	0	0	1
		3	8918	63	146	0	0	0	1
		4	8867	51	146	0	0	0	1
		5	8831	36	146	0	0	0	1
		6	8780	51	146	0	0	0	1
		7	8649	131	146	0	0	0	1
		8	8518	131	146	0	0	0	1
		9	8480	38	146	0	0	0	1
		10	8444	36	146	0	0	0	1
		11	8408	36	146	0	0	0	1
		12	8371	37	146	0	0	0	1
	2014	1	8365	6	146	0	0	0	1
		2	8305	60	146	0	0	0	1
		3	8289	16	146	0	0	0	1
		4	8239	50	146	0	0	0	1
		5	8223	16	146	0	0	0	1
		6	8186	37	146	0	0	0	1
		7	8148	38	146	0	0	0	1
		8	8082	66	146	0	0	0	1
		9	8023	59	146	0	0	0	1
		10	7933	90	146	0	0	0	1
		11	7733	200	146	0	0	0	1
		12	7717	16	146	0	0	0	1
	2015	1	7624	93	146	0	0	0	1
		2	7572	52	146	0	0	0	1
		3	7447	125	146	0	0	0	1
		4	7423	24	146	0	0	0	1
		5	7368	55	146	0	0	0	1
		6	7168	200	146	0	0	0	1
		7	7115	53	146	0	0	0	1
		8	7004	111	146	0	0	0	1
		9	6777	227	146	0	0	0	1
		10	6652	125	146	0	0	0	1
		11	6638	14	146	0	0	0	1
		12	6548	90	146	0	0	0	1

	Year	Month	Inventory	Demand	S Alternative	Order	Receipt	On Order	L
Forecasting	2016	1	6454	94	146	0	0	0	1
		2	6422	32	146	0	0	0	1
		3	6408	14	146	0	0	0	1
		4	6358	50	146	0	0	0	1
		5	6140	218	146	0	0	0	1
		6	6009	131	146	0	0	0	1
		7	5915	94	146	0	0	0	1
		8	5822	93	146	0	0	0	1
		9	5765	57	146	0	0	0	1
		10	5733	32	146	0	0	0	1
		11	5674	59	146	0	0	0	1
		12	5580	94	146	0	0	0	1
	2017	1	5490	90	146	0	0	0	1
		2	5269	221	146	0	0	0	1
		3	5263	6	146	0	0	0	1
		4	5132	131	146	0	0	0	1
		5	5072	60	146	0	0	0	1
		6	5022	50	146	0	0	0	1
		7	5006	16	146	0	0	0	1
		8	4913	93	146	0	0	0	1
		9	4819	94	146	0	0	0	1
		10	4781	38	146	0	0	0	1
		11	4745	36	146	0	0	0	1
		12	4729	16	146	0	0	0	1

Table 3.5 Comparisons

s	S	Total Order	Order Cost	Total Inventory	Holding Cost	Unit Price	Total Cost	Z value	SL
73	115	0	$35	418522	$34.8	$174	$14,564,566	50.00%	99.95%
88	130	0	$35	418522	$34.8	$174	$14,564,566	61.03%	99.95%
104	146	0	$35	419422	$34.8	$174	$14,595,886	71.23%	99.95%
121	163	0	$35	418522	$34.8	$174	$14,564,566	81.06%	99.95%
146	188	0	$35	418522	$34.8	$174	$14,564,566	90.66%	99.95%
166	208	0	$35	418522	$34.8	$174	$14,564,566	95.35%	99.95%
188	230	0	$35	418522	$34.8	$174	$14,564,566	98.12%	99.95%
261	303	0	$35	418522	$34.8	$174	$14,564,566	99.97%	99.95%

Table 3.6 Options

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	166	208	0	418522	$14,564,566	99.95%
Simulation	73	115	0	418522	$14,564,566	99.95%
	88	130	0	418522	$14,564,566	99.95%
	104	146	0	418522	$14,564,566	99.95%

Appendix 4 Valve Parts Detail Calculation

Table 4.1 Random Number

Demand	Frequency	Proportion	Cum. Proportion	Interval Proportion
0	7	0.194	0.194	0.000 - 0.194
1	6	0.167	0.361	0.195 - 0.361
2	3	0.083	0.444	0.362 - 0.444
3	2	0.056	0.500	0.445 - 0.500
4	2	0.056	0.556	0.501 - 0.556
5	2	0.056	0.611	0.557 - 0.611
6	2	0.056	0.667	0.612 - 0.667
11	1	0.028	0.694	0.668 - 0.694
14	1	0.028	0.722	0.695 - 0.722
23	2	0.056	0.778	0.723 - 0.778
38	1	0.028	0.806	0.779 - 0.806
40	1	0.028	0.833	0.807 - 0.833
45	1	0.028	0.861	0.834 - 0.861
72	1	0.028	0.889	0.862 - 0.889
87	1	0.028	0.917	0.890 - 0.917
122	1	0.028	0.944	0.918 - 0.944
140	1	0.028	0.972	0.945 - 0.972
177	1	0.028	1.000	0.973 - 1.000

Table 4.2 Forecasted Demand

Generate Random	Demand
0.340	5
0.034	0
0.145	140
0.260	23
0.778	87
0.139	2
0.158	2
0.519	0
0.105	1
0.425	0
0.586	122

Generate Random	Demand
0.802	2
0.111	0
0.768	1
0.910	0
0.390	0
0.486	0
0.758	140
0.020	4
0.679	0
0.265	0
0.596	1
0.017	14
0.482	0
0.255	0
0.490	3
0.422	1
0.487	0
0.585	1
0.541	14
0.506	4
0.768	0
0.386	45
0.021	14
0.198	5
0.160	0
0.270	177
0.196	2
0.595	38
0.828	3
0.003	87
0.750	0
0.919	23
0.944	11
0.870	6
0.019	0
0.755	87
0.165	0
0.250	5
0.417	140
0.845	0
0.058	1
0.022	40
0.645	5

Generate Random	Demand
0.473	38
0.215	0
0.167	11
0.895	5
0.236	2
0.874	140
0.340	5
0.034	0
0.145	140

Table 4.3 s, S Formulation

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	1113	1	112	0	0	0	1
		2	1110	5	112	2	2	0	1
		3	990	122	112	2	2	0	1
		4	1044	87	112	141	141	0	1
		5	1058	1	112	15	15	0	1
		6	1059	0	112	6	1	0	1
		7	1074	4	112	14	19	0	1
		8	1044	38	112	8	8	0	1
		9	1043	6	112	5	5	0	1
		10	1043	5	112	5	5	0	1
		11	1011	45	112	18	13	0	1
		12	1027	2	112	15	18	0	1
	2011	1	1027	0	112	1	0	0	1
		2	1070	4	112	44	47	0	1
		3	1034	40	112	4	4	0	1
		4	1170	0	112	197	136	0	1
		5	1261	72	112	111	163	0	1
		6	1254	23	112	7	16	0	1
		7	1250	3	112	0	0	0	1
		8	1270	0	112	31	20	0	1
		9	1270	14	112	14	14	0	1
		10	1272	1	112	3	3	0	1
		11	1286	1	112	4	15	0	1
		12	1284	2	112	0	0	0	1
	2012	1	1151	140	112	17	7	0	1
		2	1090	177	112	106	116	0	1
		3	1086	6	112	2	2	0	1
		4	1170	11	112	95	95	0	1
		5	1188	0	112	18	18	0	1
		6	1176	23	112	11	11	0	1
		7	1492	1	112	317	317	0	1
		8	1492	0	112	0	0	0	1
		9	1489	3	112	0	0	0	1
		10	1493	0	112	6	4	0	1
		11	1605	1	112	111	113	0	1
		12	1603	2	112	2	0	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	1598	5	112	0	0	0	1
		2	1598	0	112	0	0	0	1
		3	1458	140	112	0	0	0	1
		4	1435	23	112	0	0	0	1
		5	1348	87	112	0	0	0	1
		6	1346	2	112	0	0	0	1
		7	1344	2	112	0	0	0	1
		8	1344	0	112	0	0	0	1
		9	1343	1	112	0	0	0	1
		10	1343	0	112	0	0	0	1
		11	1221	122	112	0	0	0	1
		12	1219	2	112	0	0	0	1
	2014	1	1219	0	112	0	0	0	1
		2	1218	1	112	0	0	0	1
		3	1218	0	112	0	0	0	1
		4	1218	0	112	0	0	0	1
		5	1218	0	112	0	0	0	1
		6	1078	140	112	0	0	0	1
		7	1074	4	112	0	0	0	1
		8	1074	0	112	0	0	0	1
		9	1074	0	112	0	0	0	1
		10	1073	1	112	0	0	0	1
		11	1059	14	112	0	0	0	1
		12	1059	0	112	0	0	0	1
	2015	1	1059	0	112	0	0	0	1
		2	1056	3	112	0	0	0	1
		3	1055	1	112	0	0	0	1
		4	1055	0	112	0	0	0	1
		5	1054	1	112	0	0	0	1
		6	1040	14	112	0	0	0	1
		7	1036	4	112	0	0	0	1
		8	1036	0	112	0	0	0	1
		9	991	45	112	0	0	0	1
		10	977	14	112	0	0	0	1
		11	972	5	112	0	0	0	1
		12	972	0	112	0	0	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2016	1	795	177	112	0	0	0	1
		2	793	2	112	0	0	0	1
		3	755	38	112	0	0	0	1
		4	752	3	112	0	0	0	1
		5	665	87	112	0	0	0	1
		6	665	0	112	0	0	0	1
		7	642	23	112	0	0	0	1
		8	631	11	112	0	0	0	1
		9	625	6	112	0	0	0	1
		10	625	0	112	0	0	0	1
		11	538	87	112	0	0	0	1
		12	538	0	112	0	0	0	1
	2017	1	533	5	112	0	0	0	1
		2	393	140	112	0	0	0	1
		3	393	0	112	0	0	0	1
		4	392	1	112	0	0	0	1
		5	352	40	112	0	0	0	1
		6	347	5	112	0	0	0	1
		7	309	38	112	0	0	0	1
		8	309	0	112	0	0	0	1
		9	298	11	112	0	0	0	1
		10	293	5	112	0	0	0	1
		11	291	2	112	0	0	0	1
		12	151	140	112	0	0	0	1

Table 4.4 s, S Simulation

Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
2010	1	1113	1	62	0	0	0	1
	2	1110	5	62	2	2	0	1
	3	990	122	62	2	2	0	1
	4	1044	87	62	141	141	0	1
	5	1058	1	62	15	15	0	1
	6	1059	0	62	6	1	0	1
	7	1074	4	62	14	19	0	1
	8	1044	38	62	8	8	0	1
	9	1043	6	62	5	5	0	1
	10	1043	5	62	5	5	0	1
	11	1011	45	62	18	13	0	1
	12	1027	2	62	15	18	0	1
2011	1	1027	0	62	1	0	0	1
	2	1070	4	62	44	47	0	1
	3	1034	40	62	4	4	0	1
	4	1170	0	62	197	136	0	1
	5	1261	72	62	111	163	0	1
	6	1254	23	62	7	16	0	1
	7	1250	3	62	0	0	0	1
	8	1270	0	62	31	20	0	1
	9	1270	14	62	14	14	0	1
	10	1272	1	62	3	3	0	1
	11	1286	1	62	4	15	0	1
	12	1284	2	62	0	0	0	1
2012	1	1151	140	62	17	7	0	1
	2	1090	177	62	106	116	0	1
	3	1086	6	62	2	2	0	1
	4	1170	11	62	95	95	0	1
	5	1188	0	62	18	18	0	1
	6	1176	23	62	11	11	0	1
	7	1492	1	62	317	317	0	1
	8	1492	0	62	0	0	0	1
	9	1489	3	62	0	0	0	1
	10	1493	0	62	6	4	0	1
	11	1605	1	62	111	113	0	1
	12	1603	2	62	2	0	0	1

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Forecasting	2013	1	1598	5	62	0	0	0	1
		2	1598	0	62	0	0	0	1
		3	1458	140	62	0	0	0	1
		4	1435	23	62	0	0	0	1
		5	1348	87	62	0	0	0	1
		6	1346	2	62	0	0	0	1
		7	1344	2	62	0	0	0	1
		8	1344	0	62	0	0	0	1
		9	1343	1	62	0	0	0	1
		10	1343	0	62	0	0	0	1
		11	1221	122	62	0	0	0	1
		12	1219	2	62	0	0	0	1
	2014	1	1219	0	62	0	0	0	1
		2	1218	1	62	0	0	0	1
		3	1218	0	62	0	0	0	1
		4	1218	0	62	0	0	0	1
		5	1218	0	62	0	0	0	1
		6	1078	140	62	0	0	0	1
		7	1074	4	62	0	0	0	1
		8	1074	0	62	0	0	0	1
		9	1074	0	62	0	0	0	1
		10	1073	1	62	0	0	0	1
		11	1059	14	62	0	0	0	1
		12	1059	0	62	0	0	0	1
	2015	1	1059	0	62	0	0	0	1
		2	1056	3	62	0	0	0	1
		3	1055	1	62	0	0	0	1
		4	1055	0	62	0	0	0	1
		5	1054	1	62	0	0	0	1
		6	1040	14	62	0	0	0	1
		7	1036	4	62	0	0	0	1
		8	1036	0	62	0	0	0	1
		9	991	45	62	0	0	0	1
		10	977	14	62	0	0	0	1
		11	972	5	62	0	0	0	1
		12	972	0	62	0	0	0	1

	Year	Month	Inventory	Demand	S Alternative	Order	Receipt	On Order	L
Forecasting	2016	1	795	177	62	0	0	0	1
		2	793	2	62	0	0	0	1
		3	755	38	62	0	0	0	1
		4	752	3	62	0	0	0	1
		5	665	87	62	0	0	0	1
		6	665	0	62	0	0	0	1
		7	642	23	62	0	0	0	1
		8	631	11	62	0	0	0	1
		9	625	6	62	0	0	0	1
		10	625	0	62	0	0	0	1
		11	538	87	62	0	0	0	1
		12	538	0	62	0	0	0	1
	2017	1	533	5	62	0	0	0	1
		2	393	140	62	0	0	0	1
		3	393	0	62	0	0	0	1
		4	392	1	62	0	0	0	1
		5	352	40	62	0	0	0	1
		6	347	5	62	0	0	0	1
		7	309	38	62	0	0	0	1
		8	309	0	62	0	0	0	1
		9	298	11	62	0	0	0	1
		10	293	5	62	0	0	0	1
		11	291	2	62	0	0	0	1
		12	151	140	62	0	0	0	1

Table 4.5 Comparisons

s	S	Total Order	Order Cost	Total Inventory	Holding Cost	Unit Price	Total Cost	Z value	SL
24	36	0	$35	54567	$131	$653	$7,126,450	50.00%	99.89%
37	49	0	$35	54567	$131	$653	$7,126,450	61.03%	99.89%
50	62	0	$35	54567	$131	$653	$7,126,450	71.23%	99.89%
64	76	0	$35	54567	$131	$653	$7,126,450	81.06%	99.89%
84	96	0	$35	54567	$131	$653	$7,126,450	90.66%	99.89%
100	112	0	$35	54567	$131	$653	$7,126,450	95.35%	99.89%
118	130	0	$35	54567	$131	$653	$7,126,450	98.12%	99.89%
178	190	0	$35	54567	$131	$653	$7,126,450	99.97%	99.89%

Table 4.6 Options

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	100	112	0	54567	$7,126,450	99.89%
Simulation	24	36	0	54567	$7,126,450	99.89%
	37	49	0	54567	$7,126,450	99.89%
	50	62	0	54567	$7,126,450	99.89%

Appendix 5 Turbine Hardware Parts Detail Calculation

Table 5.1 Random Number

Demand	Frequency	Proportion	Cum. Proportion	Interval Proportion
0	10	0.278	0.278	0.000 - 0.278
1	8	0.222	0.500	0.279 - 0.500
2	2	0.056	0.556	0.501 - 0.556
10	2	0.056	0.611	0.557 - 0.611
25	1	0.028	0.639	0.612 - 0.639
41	1	0.028	0.667	0.640 - 0.667
60	1	0.028	0.694	0.668 - 0.694
147	1	0.028	0.722	0.695 - 0.722
154	1	0.028	0.750	0.723 - 0.750
228	1	0.028	0.778	0.751 - 0.778
337	1	0.028	0.806	0.779 - 0.806
473	1	0.028	0.833	0.807 - 0.833
672	1	0.028	0.861	0.834 - 0.861
989	1	0.028	0.889	0.862 - 0.889
1031	1	0.028	0.917	0.890 - 0.917
1136	1	0.028	0.944	0.918 - 0.944
1576	1	0.028	0.972	0.945 - 0.972
3214	1	0.028	1.000	0.973 - 1.000

Table 5.2 Forecasted Demand

Generate Random	Demand
0.898	1031
0.299	1
0.120	0
0.988	3214
0.960	1576
0.536	2
0.712	147
0.666	41
0.373	1
0.636	25
0.634	25
0.923	1136
0.458	1

Generate Random	Demand
0.748	154
0.531	2
0.644	41
0.647	41
0.440	1
0.827	473
0.434	1
0.381	1
0.864	989
0.132	0
0.105	0
0.833	473
0.751	228
0.718	147
0.544	2
0.867	989
0.647	41
0.547	2
0.222	0
0.590	10
0.538	2
0.977	3214
0.237	0
0.650	41
0.262	0
0.830	473
0.935	1136
0.139	0
0.959	1576
0.924	1136
0.878	989
0.228	0
0.843	672
0.480	1
0.943	1136
0.773	228
0.700	147
0.788	337
0.580	10
0.585	10
0.936	1136
0.028	0
0.196	0

Generate Random	Demand
0.178	0
0.587 0.868	10 989
0.025	0
0.898	1031
0.299	1
0.120	0

Table 5.3 s, S Formulation

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Existing	2010	1	34704	1	1694	0	0	0	1
		2	34712	2	1694	14	10	0	1
		3	34484	228	1694	0	0	0	1
		4	33877	672	1694	61	65	0	1
		5	33876	1	1694	146	0	0	1
		6	34005	1	1694	1	130	0	1
		7	33945	60	1694	0	0	0	1
		8	33936	10	1694	1	1	0	1
		9	33937	0	1694	0	1	0	1
		10	33930	10	1694	3	3	0	1
		11	32810	1136	1694	0	16	0	1
		12	32785	25	1694	0	0	0	1
	2011	1	32785	0	1694	0	0	0	1
		2	32784	1	1694	0	0	0	1
		3	32787	0	1694	3	3	0	1
		4	32787	2	1694	2	2	0	1
		5	31798	989	1694	0	0	0	1
		6	31798	0	1694	0	0	0	1
		7	31653	147	1694	2	2	0	1
		8	31654	0	1694	1	1	0	1
		9	31654	1	1694	1	1	0	1
		10	31721	1	1694	68	68	0	1
		11	31567	154	1694	0	0	0	1
		12	31568	0	1694	1	1	0	1
	2012	1	30537	1031	1694	0	0	0	1
		2	28961	1576	1694	0	0	0	1
		3	28961	0	1694	0	0	0	1
		4	28961	0	1694	0	0	0	1
		5	25748	3214	1694	1	1	0	1
		6	25707	41	1694	0	0	0	1
		7	25706	1	1694	0	0	0	1
		8	25706	0	1694	0	0	0	1
		9	25708	1	1694	3	3	0	1
		10	25371	337	1694	0	0	0	1
		11	24898	473	1694	0	0	0	1
		12	24898	0	1694	13	0	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2013	1	23867	1031	1694	0	0	0	1
		2	23866	1	1694	0	0	0	1
		3	23866	0	1694	0	0	0	1
		4	20652	3214	1694	0	0	0	1
		5	19076	1576	1694	0	0	0	1
		6	19074	2	1694	0	0	0	1
		7	18927	147	1694	0	0	0	1
		8	18886	41	1694	0	0	0	1
		9	18885	1	1694	0	0	0	1
		10	18860	25	1694	0	0	0	1
		11	18835	25	1694	0	0	0	1
		12	17699	1136	1694	0	0	0	1
	2014	1	17698	1	1694	0	0	0	1
		2	17544	154	1694	0	0	0	1
		3	17542	2	1694	0	0	0	1
		4	17501	41	1694	0	0	0	1
		5	17460	41	1694	0	0	0	1
		6	17459	1	1694	0	0	0	1
		7	16986	473	1694	0	0	0	1
		8	16985	1	1694	0	0	0	1
		9	16984	1	1694	0	0	0	1
		10	15995	989	1694	0	0	0	1
		11	15995	0	1694	0	0	0	1
		12	15995	0	1694	0	0	0	1
	2015	1	15522	473	1694	0	0	0	1
		2	15294	228	1694	0	0	0	1
		3	15147	147	1694	0	0	0	1
		4	15145	2	1694	0	0	0	1
		5	14156	989	1694	0	0	0	1
		6	14115	41	1694	0	0	0	1
		7	14113	2	1694	0	0	0	1
		8	14113	0	1694	0	0	0	1
		9	14103	10	1694	0	0	0	1
		10	14101	2	1694	0	0	0	1
		11	10887	3214	1694	0	0	0	1
		12	10887	0	1694	0	0	0	1

	Year	Month	Inventory	Demand	S Formula	Order	Receipt	On Order	L
Forecasting	2016	1	10846	41	1694	0	0	0	1
		2	10846	0	1694	0	0	0	1
		3	10373	473	1694	0	0	0	1
		4	9237	1136	1694	0	0	0	1
		5	9237	0	1694	0	0	0	1
		6	7661	1576	1694	0	0	0	1
		7	6525	1136	1694	0	0	0	1
		8	5536	989	1694	0	0	0	1
		9	5536	0	1694	0	0	0	1
		10	4864	672	1694	0	0	0	1
		11	4863	1	1694	0	0	0	1
		12	3727	1136	1694	0	0	0	1
	2017	1	3499	228	1694	0	0	0	1
		2	3352	147	1694	0	0	0	1
		3	3015	337	1694	0	0	0	1
		4	3005	10	1694	0	0	0	1
		5	2995	10	1694	0	0	0	1
		6	1859	1136	1694	0	0	0	1
		7	1859	0	1694	0	0	0	1
		8	1859	0	1694	0	0	0	1
		9	1859	0	1694	0	0	0	1
		10	1849	10	1694	0	0	0	1
		11	860	989	1694	0	0	0	1
		12	860	0	1694	834	0	0	1

Table 5.4 s, S Simulation

Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
2010	1	34704	1	910	0	0	0	1
	2	34712	2	910	14	10	0	1
	3	34484	228	910	0	0	0	1
	4	33877	672	910	61	65	0	1
	5	33876	1	910	146	0	0	1
	6	34005	1	910	1	130	0	1
	7	33945	60	910	0	0	0	1
	8	33936	10	910	1	1	0	1
	9	33937	0	910	0	1	0	1
	10	33930	10	910	3	3	0	1
	11	32810	1136	910	0	16	0	1
	12	32785	25	910	0	0	0	1
2011	1	32785	0	910	0	0	0	1
	2	32784	1	910	0	0	0	1
	3	32787	0	910	3	3	0	1
	4	32787	2	910	2	2	0	1
	5	31798	989	910	0	0	0	1
	6	31798	0	910	0	0	0	1
	7	31653	147	910	2	2	0	1
	8	31654	0	910	1	1	0	1
	9	31654	1	910	1	1	0	1
	10	31721	1	910	68	68	0	1
	11	31567	154	910	0	0	0	1
	12	31568	0	910	1	1	0	1
2012	1	30537	1031	910	0	0	0	1
	2	28961	1576	910	0	0	0	1
	3	28961	0	910	0	0	0	1
	4	28961	0	910	0	0	0	1
	5	25748	3214	910	1	1	0	1
	6	25707	41	910	0	0	0	1
	7	25706	1	910	0	0	0	1
	8	25706	0	910	0	0	0	1
	9	25708	1	910	3	3	0	1
	10	25371	337	910	0	0	0	1
	11	24898	473	910	0	0	0	1
	12	24898	0	910	13	0	0	1

	Year	Month	Inventory	Demand	S Alternatif	Order	Receipt	On Order	L
Forecasting	2013	1	23867	1031	910	0	0	0	1
		2	23866	1	910	0	0	0	1
		3	23866	0	910	0	0	0	1
		4	20652	3214	910	0	0	0	1
		5	19076	1576	910	0	0	0	1
		6	19074	2	910	0	0	0	1
		7	18927	147	910	0	0	0	1
		8	18886	41	910	0	0	0	1
		9	18885	1	910	0	0	0	1
		10	18860	25	910	0	0	0	1
		11	18835	25	910	0	0	0	1
		12	17699	1136	910	0	0	0	1
	2014	1	17698	1	910	0	0	0	1
		2	17544	154	910	0	0	0	1
		3	17542	2	910	0	0	0	1
		4	17501	41	910	0	0	0	1
		5	17460	41	910	0	0	0	1
		6	17459	1	910	0	0	0	1
		7	16986	473	910	0	0	0	1
		8	16985	1	910	0	0	0	1
		9	16984	1	910	0	0	0	1
		10	15995	989	910	0	0	0	1
		11	15995	0	910	0	0	0	1
		12	15995	0	910	0	0	0	1
	2015	1	23867	1031	910	0	0	0	1
		2	23866	1	910	0	0	0	1
		3	23866	0	910	0	0	0	1
		4	20652	3214	910	0	0	0	1
		5	19076	1576	910	0	0	0	1
		6	19074	2	910	0	0	0	1
		7	18927	147	910	0	0	0	1
		8	18886	41	910	0	0	0	1
		9	18885	1	910	0	0	0	1
		10	18860	25	910	0	0	0	1
		11	18835	25	910	0	0	0	1
		12	17699	1136	910	0	0	0	1

	Year	Month	Inventory	Demand	S Alternative	Order	Receipt	On Order	L
Forecasting	2016	1	10846	41	910	0	0	0	1
		2	10846	0	910	0	0	0	1
		3	10373	473	910	0	0	0	1
		4	9237	1136	910	0	0	0	1
		5	9237	0	910	0	0	0	1
		6	7661	1576	910	0	0	0	1
		7	6525	1136	910	0	0	0	1
		8	5536	989	910	0	0	0	1
		9	5536	0	910	0	0	0	1
		10	4864	672	910	0	0	0	1
		11	4863	1	910	0	0	0	1
		12	3727	1136	910	0	0	0	1
	2017	1	3499	228	910	0	0	0	1
		2	3352	147	910	0	0	0	1
		3	3015	337	910	0	0	0	1
		4	3005	10	910	0	0	0	1
		5	2995	10	910	0	0	0	1
		6	1859	1136	910	0	0	0	1
		7	1859	0	910	0	0	0	1
		8	1859	0	910	0	0	0	1
		9	1859	0	910	0	0	0	1
		10	1849	10	910	0	0	0	1
		11	860	989	910	0	0	0	1
		12	860	0	910	50	0	0	1

Table 5.5 Comparisons

s	S	Total Order	Order Cost	Total Inventory	Holding Cost	Unit Price	Total Cost	Z value	SL
401	519	0	$35	730342	$24.2	$121	$17,674,276	50.00%	99.92%
596	714	0	$35	730342	$24.2	$121	$17,674,276	61.03%	99.92%
792	910	50	$35	730342	$24.2	$121	$17,676,026	71.23%	99.92%
1016	1134	274	$35	730342	$24.2	$121	$17,683,866	81.06%	99.92%
1324	1442	582	$35	730342	$24.2	$121	$17,694,646	90.66%	99.92%
1576	1694	834	$35	730342	$24.2	$121	$17,703,466	95.35%	99.92%
1855	1973	1237	$35	730466	$24.2	$121	$17,720,572	98.12%	99.92%
2779	2897	2076	$35	739684	$24.2	$121	$17,973,013	99.97%	99.92%

Table 5.6 Options

	s	S	Total Order	Total Inventory	Total Cost	SL
Formula	1576	1694	834	730342	$17,703,466	99.92%
Simulation	401	519	0	730342	$17,674,276	99.92%
	596	714	0	730342	$17,674,276	99.92%
	792	910	50	730342	$17,676,026	99.92%

Dhini Syalina lahir di Pekanbaru, Riau. Setelah menamatkan pendidikan Sekolah Menengah Umum (SMU) di SMU Cendana Mandau, Riau, penulis melanjutkan studi di Jurusan Akuntasi Fakultas Ekonomi Internasional Program, Universitas Islam Indonesia, Yogyakarta pada tahun 2002. Setelah menamatkan perkuliahan, penulis bekerja di PT Pec-Tech Services Indonesia selama kurang lebih 4 tahun dari tahun 2006 sampai 2010 di posisi terakhir sebagai cost controller head divisi Harvesting. Pada tahun 2011 sampai sekarang, penulis bekerja di North Duri Cogen Plant, PT. Chevron Geothermal Indonesia sebagai Business Planning Specialist. dan mendapatkan penugasan di Sumatera operations. Penulis meneruskan studi pada tahun 2011 dengan menempuh program Pascasarjana Magister Manajemen Teknologi ITS bidang keahlian Manajemen Proyek hingga tahun 2013. Penulis mengambil judul tesis *"Continuous Review Approach to Control Materials Inventory : A Case Study"*.